

UNIFIED FACILITIES CRITERIA (UFC)

ELECTRICAL ENGINEERING



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U.S. ARMY CORPS OF ENGINEERS

NAVAL FACILITIES ENGINEERING SYSTEMS COMMAND (Preparing Activity)

AIR FORCE CIVIL ENGINEER CENTER

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FOREWORD

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

UFC are living documents and will be periodically reviewed, updated, and made available to users as part of the Military Department's responsibility for providing technical criteria for military construction. Headquarters, U.S. Army Corps of Engineers (HQUSACE), Naval Facilities Engineering Systems Command (NAVFAC), and Air Force Civil Engineer Center (AFCEC) are responsible for administration of the UFC system. Technical content of UFC is the responsibility of the cognizant DoD working group. Defense Agencies should contact the respective DoD Working Group for document interpretation and improvements. Recommended changes with supporting rationale may be sent to the respective DoD working group by submitting a Criteria Change Request (CCR) via the Internet site listed below.

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

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

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

AUTHORIZED BY:



PETE G. PEREZ, P.E., SES
Chief, Engineering and Construction
U.S. Army Corps of Engineers



S. KEITH HAMILTON, P.E., SES
Chief Engineer and Assistant Commander
Planning, Design and Construction
Naval Facilities Engineering Systems Command



THOMAS P. BROWN, SES
Deputy Director of Civil Engineers
DCS/Logistics, Engineering &
Force Protection (HAF/A4C)
HQ United States Air Force



MICHAEL McANDREW, SES
Deputy Assistant Secretary of Defense
(Infrastructure Modernization and Resilience)
Office of the Secretary of Defense

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CHAPTER 1 INTRODUCTION

1-1 PURPOSE AND SCOPE.

The purpose of this UFC is to provide technical requirements for general aspects of the electrical design of projects. Apply the criteria provided in this UFC for the development of the plans, specifications, calculations, and Design/Build Request for Proposals (RFP). It serves as the minimum electrical design requirements for design-build and design-bid-build projects. Project conditions may dictate the need for a design that exceeds these minimum requirements.

1-1.1 UFC Hierarchy.

This UFC provides the top-tier baseline requirements for electrical UFCs and is intended as a reference for all electrical work on projects. All electrical UFCs listed in Appendix E rely on this UFC for overall requirements regarding design analysis and documentation.

1-1.2 Upgrades and Modifications to Existing Systems.

Modernization of electrical systems solely for the purpose of meeting design criteria in UFCs is not required. Upgrades or modifications to electrical systems should consider the design criteria in this UFC, but it is not intended that an entire facility or system require modernization solely because of a minor modification.

For minor projects, determine if the project will affect existing electrical system calculations such as by modifying circuit breaker settings. If any electrical system calculations are affected by the modification, update the calculations, including the arc flash calculation, as part of the project.

Note: Arc flash calculation updates are necessary for electrical safety.

1-2 REISSUES AND CANCELS.

This UFC reissues and cancels UFC 3-501-01, *Electrical Engineering*, dated 06 October 2015.

1-3 APPLICABILITY.

This UFC applies to the planning, design, construction, sustainment, restoration, and modernization of DoD-owned facilities. It is applicable to all methods of project delivery and levels of construction as defined by UFC 1-200-01 section 1-3.

1-4 GENERAL BUILDING REQUIREMENTS.

Comply with UFC 1-200-01, *DoD Building Code*. UFC 1-200-01 provides applicability of model building codes and government unique criteria for typical design disciplines and

building systems, as well as for accessibility, antiterrorism, security, high performance and sustainability requirements, and safety. Use this UFC in addition to UFC 1-200-01 and the UFCs and government criteria referenced therein.

1-5 WAIVER AND EXEMPTIONS PROCESS.

The waiver and exemption process is provided in MIL-STD 3007.

1-6 CYBERSECURITY.

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

1-7 PERMITS – CONSTRUCTION, ENVIRONMENTAL, AND OTHER.

Identify the permits and fees necessary for environmental, construction, and operation of facilities.

1-8 GLOSSARY.

APPENDIX D contains acronyms, abbreviations, and terms.

1-9 REFERENCES.

APPENDIX E contains a list of references used in this document. The publication date of the code or standard is not included in this document. Unless otherwise specified, the most recent edition of the referenced publication applies. If dates are not indicated in the contract or in the absence or other direction, the issue/version of publication in effect at the time the design started is to be used. Designs that have been started and then delayed will need to evaluate which version is applicable and may have to update to the newer version if considerable time has gone by. This may require some redesign.

CHAPTER 2 TECHNICAL REQUIREMENTS

2-1 GENERAL.

Design electrical systems to meet the needs of the activity and supporting facilities in accordance with this document.

Provide electrical equipment that is the manufacturer's standard catalog products, conforming to the latest published industry and technical society standards at the date of contract award. Underwriters Laboratories (UL) listing or third-party certification is required for all basic equipment. Use of shop or field fabricated electrical equipment assemblies that are not manufacturer's standard catalog products or do not conform to the industry and technical society standards are not acceptable.

2-1.1 Removal of Existing Cables and Conductors.

When a project requires disconnection of existing cables and conductors enclosed in either duct or conduit, physically remove the existing cables and conductors. Associated ducts or conduits may be abandoned in place only for the following conditions:

- They are planned for re-use.
- Removal will cause substantial facility damage.
- Conduits are inaccessible.

On duct systems between underground structures (handholes, manholes, and vaults), provide a pull wire (string or rope) for future use, and seal both ends of duct. Apply label to each end of the pull rope noting the location of the other end of the conduit.

2-1.2 Hot Caps and Removal of T-Splices Inside Manholes.

Regardless of voltage, do not hot cap conductors in a manhole or handhole as part of demolition.

If the conductor is part of a T-splice or Y-splice that is being removed, remove the splice and install an in-line splice for the remaining conductors. For the Army and Navy, if the conductor is part of a T-splice or Y-splice that is being re-used, a hot cap is allowed during construction to maintain an energized circuit.

Note: Hot caps are only allowed as a temporary method during construction to maintain an energized circuit.

2-1.3 Modification to Existing Electrical Equipment.

Uniquely identify equipment to be "Modified" or "Added to" and include the manufacturer's name and other pertinent manufacturer's identification (e.g., serial number, model number, style), if such information exists.

2-1.4 Salvaged Materials and Equipment.

Demolition projects may require equipment or material to be salvaged for, or by the Government. Uniquely identify all salvageable equipment or material. Include the manufacturer's name and other pertinent manufacturer's identification including serial number, model number, style, physical dimensions, and weight if such information exists. Indicate who is responsible for removal, storage, and transportation.

2-1.5 Scheduling and Sequencing Outages.

Designer of Record must:

- Determine and address scheduling, sequencing, and outage requirements including anticipated outage durations as a part of contract design documents. Provide a specific and detailed suggested sequence of construction. Identify any temporary requirements, including the need for emergency generators for backup power during construction-related outages.
- Require the contractor to review all identified requirements and submit outage requests for approval by the Government prior to initiating the specific work task.
- Require that all work complies with the electrical safety requirements contained in UFC 3-560-01 for government workers and EM 385-1-1 for contractor work.

Note: UFC 3-560-01 is usually more stringent than EM 385-1-1. However, it may be invoked on contractor work when desired and agreed to by the Activity. In that case, include the appropriate requirements during the design phase in the contract documents.

2-1.6 Energy Efficiency and Sustainable Design.

Comply with UFC 1-200-02.

2-1.7 Antiterrorism and Physical Security.

UFC 4-010-01 is a multidiscipline document which contains several standards that may impact electrical system design. Electrical designers must be familiar with UFC 4-010-01 and how it may affect the design of utilities, service entrance equipment, emergency backup systems, and bracing of electrical equipment. Incorporate the minimum standards into the design of all new construction and major renovations of inhabited DoD buildings. UFC 4-020-01 supports the planning of DoD facilities that include requirements for security and antiterrorism. Use in conjunction with UFC 4-010-01 to establish the security and antiterrorism design criteria that will be the basis for DoD facility designs.

2-1.8 Facility Systems Safety.

Incorporating safety into the engineering and design process is an important part of designing, constructing and maintaining safe facilities for use by U.S. Military, U.S. Government, and Contractor personnel. To the extent practicable and feasible, incorporate the safety engineering practices delineated under the Facilities Systems Safety (FASS) program as prescribed under OPNAV M-5100.23 Chapter 38 and DA PAM 385-16.

Ensure systems safety engineering related to equipment access and proper equipment clearances are addressed during a FASS review at the earliest phases of project development when remedies and solutions are more easily addressed rather than during construction or after facility turnover.

2-1.9 Corrosive and High Humidity Areas.

The special design requirements listed below apply when electrical equipment is routinely subjected to salt spray (such as installations at piers and wharves) or is installed in locations exposed to condensing humidity that has historically caused premature rusting and degradation of equipment enclosures. Coordinate with local Activity to obtain historical information and documentation to validate requirements.

- Provide an entire corrosion resistant transformer assembly, fabricated of stainless steel.
- Use stainless steel cabinets and hardware for pad-mounted switchgear, switchboards, and sectionalizing termination cabinets.

Note: When feasible, sectionalizing termination cabinets can be designed to comply with NEMA 4X non-metallic enclosure requirements instead of stainless steel if the enclosures are not subject to physical or structural integrity damage.

- Use stainless steel enclosures and hardware for exterior safety switches and other electrical equipment.
- Do not use aluminum-conductor steel-reinforced (ACSR) overhead conductors.
- Use weatherproof stainless steel or aluminum enclosures for outdoor engine generator applications.
- Use corrosion-resistant materials for other electrical components, such as conduit, conduit supports, couplings, fittings, plugs, connectors, receptacles, equipment supports, and luminaires.

2-1.10 Arc Flash Warning Labels.

Refer to UFC 3-560-01 for arc flash label requirements.

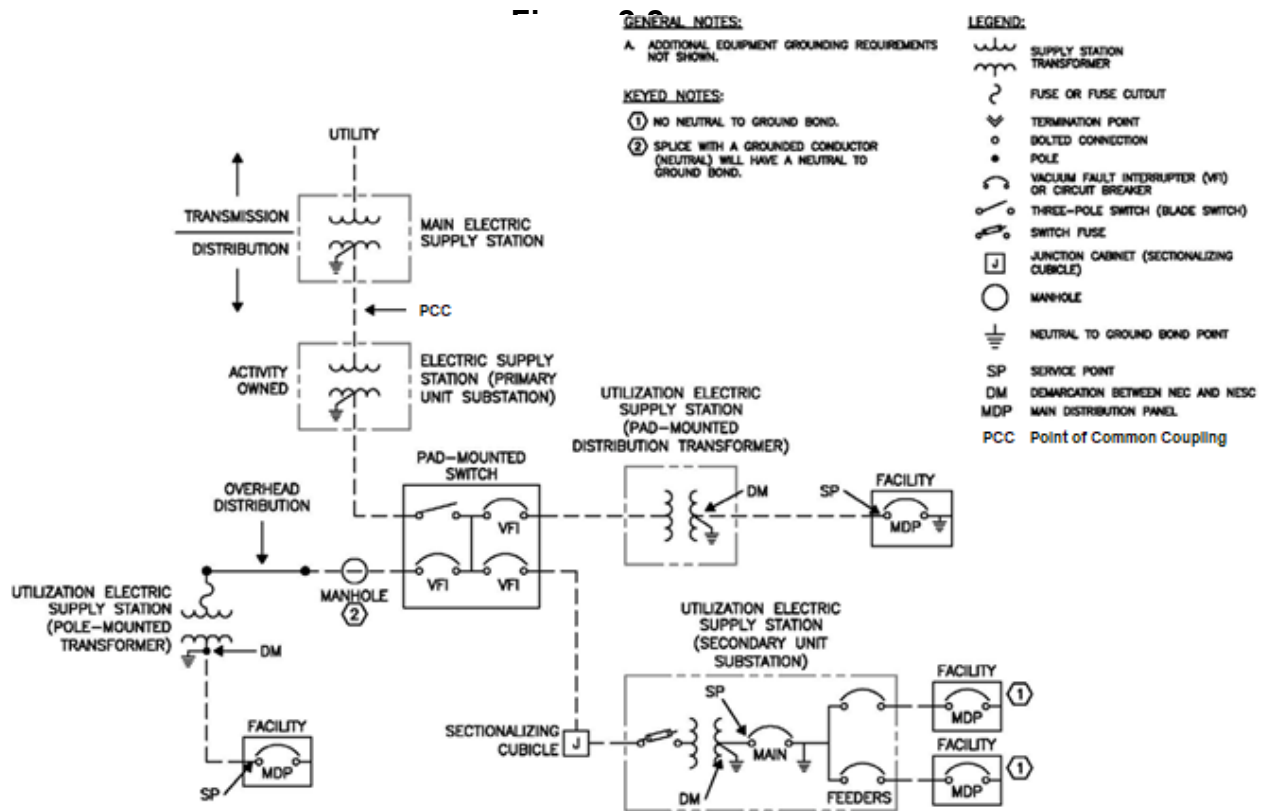
2-1.11 NFPA 70 (NEC) / IEEE C2 (NESC) Design Interface Points.

Design buildings and similar support structures such as piers, wharfs, parking structures, sewage pump stations, and fueling facilities in accordance with the general requirements of NFPA 70:

- a. Services. Apply the following:
 - The location for the “service point” (for clarification of the NFPA 70 Article 100 and IEEE C2 Section definitions): at the building/similar support structure service equipment which contains the main incoming overcurrent protective device.
 - The demarcation between NFPA 70 and IEEE C2 for electrical power design purposes: is always the secondary terminal of the building/support structure utilization electric supply system.
 - The demarcation between NFPA 70 and IEEE C2 for communication and security systems design purposes: is always the incoming service interface equipment including the five-foot raceway extension outside the building/support structure.

Figure 2-1 illustrates the above in graphic form.
- b. Exterior branch circuits. Design the following in accordance with the general requirements of NFPA 70:
 - Exterior lighting systems (parking lot, roadway, security, and sports).
 - Exterior branch or feeder circuits originating from building/support structure service equipment.
 - Wiring from and connections to non-utility equipment supplying power to the wiring system of the facility or the low-voltage terminals of the medium-voltage distribution system, including engine-generator sets, photovoltaic power systems, wind turbines, and fuel cells.
- c. Design all exterior underground and overhead, medium, and low voltage systems not specifically associated with a building/support structure in accordance with the general requirements of IEEE C2 except utilize the NFPA 70 ampacity and conduit fill tables for all designs.

Figure 2-1 Illustration of NFPA 70 Service Point and NFPA 70 / IEEE C2 Demarcation



2-2 SITE EXTERIOR POWER DISTRIBUTION SYSTEMS..

Provide the site utility distribution system that is compatible with the existing system and comply with UFC 3-550-01. Where the site service is derived from an existing primary feeder, the designer of record must coordinate with the government authority and receive direction regarding point of connection and concurrence that existing circuit can support the new loads.

Coordinate remote monitoring and control requirements for exterior distribution system equipment with the Activity.

2-2.1 Exterior Power Distribution Systems, Including Housing.

Comply with UFC 3-550-01.

2-2.2 Dockside Utilities for Ship Service.

Comply with UFC 4-150-02.

2-2.3 Exterior Lighting Systems.

Comply with UFC 3-530-01.

2-2.4 Airfield Lighting.

Comply with UFC 3-535-01.

2-2.5 Cathodic Protection Systems.

Comply with UFC 3-570-01

2-2.6 High-Altitude Electromagnetic Pulse (HEMP) Shielded Systems – Exterior.

Comply with MIL-STD-188-125-1A and MIL-HDBK-423. In lieu of concrete encasement for medium voltage direct buried metal conduits (ductbank), utilize a sand bed (minimum thickness of 3" (75 mm)) and topped with a minimum of 3" (75 mm) of sand. Provide a 2" (50 mm) thick concrete cap, the width of the trench atop the sand encasement. Place detectable warning tape above the concrete cap, 12" (300 mm) below finished grade to provide easy identification for future excavations.

2-2.7 Generators.

Comply with UFC 3-540-01.

2-2.8 Renewable Energy Systems.

Comply with UFC 3-540-08.

2-2.9 Microgrids.

Comply with UFC 3-550-04.

2-3 INTERIOR DISTRIBUTION SYSTEMS.

2-3.1 Interior Electrical Systems.

Comply with UFC 3-520-01.

For Army Civil Works funded projects, the requirements of NFPA 70 Article 240.2(A)(4) do not apply if all the following conditions are met.

- a. The molded-case circuit breaker (MCCB) is considered mission critical.
- b. A new replacement for the MCCB is not commercially available.
- c. The replacement MCCB is refurbished in accordance with ANSI/PEARL Electrical Equipment Reconditioning Standard for Electrical Apparatus and Equipment used in Commercial and Industrial Applications (EERS).

- d. Any equipment requiring the use of a refurbished MCCB must be prioritized for replacement.

2-3.2 Interior Lighting Systems.

Comply with UFC 3-530-01.

2-3.3 Emergency and Standby Systems.

2-3.3.1 Exit and Emergency Lighting.

Comply with UFC 3-530-01.

2-3.3.2 Fire Alarm Systems.

Comply with UFC 3-600-01.

2-3.3.3 Generators.

Comply with UFC 3-540-01.

2-3.4 Sensitive Compartmented Information Facilities (SCIF).

Comply with UFC 4-010-05.

2-3.5 Hazardous Locations.

Show boundaries of hazardous locations on the plans and identify the type of hazard by class, division, and group.

2-3.6 Stationary and Mission Batteries.

Comply with UFC 3-520-05.

2-3.7 HEMP Shielded Systems – Interior.

Comply with MIL-STD-188-125-1A and MIL-HDBK-423.

2-3.8 Renewable Energy Systems.

Comply with UFC 3-440-01.

2-3.9 Mission Critical Power, Cooling, and Control Systems.

Comply with UFC 3-520-02.

2-4 COMMUNICATIONS AND SECURITY.

2-4.1 Telecommunication Systems.

2-4.1.1 General.

Comply with UFC 3-580-01 for interior and exterior information communications technology.

2-4.1.2 Outside Plant.

Provide underground telecommunications wiring in conduit to a depth of 24 in (610 mm). Specify concrete encased conduits for telecommunications systems in accordance with UFC 3-550-01. Unless directed otherwise by the BCO, size outside category 3 copper cable for a minimum of one pair per 100 ft² (9 m²) of building and provide a minimum of one 12 strand single-mode fiber optic cable for each facility. Coordinate cable selection and point of connection with the BCO and specify using RUS specifications.

Provide solid-state type primary communication circuit protectors with sneak current protection for all twisted pair media terminating inside a building from an overhead or underground outside plant.

2-4.1.3 BEQ/BOQ Housing.

Completely wire the building interior conforming to UFC 3-580-01.

2-4.1.4 Family Housing.

Provide a complete structured telecommunications system in accordance with UFC 3-580-01.

2-4.2 Television Systems.

Coordinate television system requirements with the activity.

2-4.3 Community Antenna Television (CATV) Systems.

Comply with UFC 3-580-01. Coordinate exterior cable installation with the local service provider and Base Communications Officer (BCO). Provide a conduit and pull wire from a point of connection to the base system and the main distribution equipment.

2-5 ELECTRONIC SECURITY SYSTEMS (ESS).

Comply with UFC 4-021-02.

2-6 MASS NOTIFICATION SYSTEMS.

Comply with UFC 4-021-01.

CHAPTER 3 DESIGN ANALYSIS AND DOCUMENTATION

3-1 GENERAL.

This chapter defines the minimum information to be provided at the various design submittal levels. During the design submittal process, the Designer of Record must clarify comments with the appropriate Government reviewer rather than wait until the next submittal to respond. Whenever possible, the Designer of Record is encouraged to meet with the reviewer to discuss comments.

3-2 DESIGN ANALYSIS.

The Design Analysis is a presentation of facts to demonstrate the concept of the project is fully understood and the design is based on sound engineering principles. As a minimum, include the following information in the Design Analysis.

3-2.1 Basis of Design.

Document design decisions throughout the design process. List any special features and alternatives that were considered. Provide a written narrative accurately addressing the electrical and telecommunication design. Describe the design approach to all electrical systems. Include the method used for sizing conductors, conduit, protective devices, and other equipment. Show all calculations used in determining capacities of electrical systems. When tables from industry standards are used in the design, indicate the title, source, and date of the document. Include a complete list of all design standards and references used for the design.

Update the Basis of Design for each submittal to accurately show the current state of the design. Include the information in the following sub-paragraphs as a minimum.

3-2.1.1 Exterior Primary Power Distribution Systems.

- Existing Primary Power Source – Identify the location of the point of connection into the existing primary system. Address the characteristics of this primary system, including ANSI voltage designation, phase, number of conductors, available fault current, and the circuit grounding classifications (ungrounded, uni-grounded, resistance grounded, or multi-grounded). Address the adequacy of the primary system; if inadequate, state measures proposed to correct the inadequacy.
- Estimated Electrical Project Load – Provide an estimate of total connected load (kVA) and the resulting demand load (kVA), transformer size, and service size.
- Voltage Selection – Provide basis for selection of primary and secondary voltages.
- Conductors – Include conductor size, type, number of conductors, insulation voltage rating, and insulation level.

- Standards of Design – Describe pertinent standards of design, such as voltage drop, and equipment ratings.
- Materials – Provide manufacturer's data sheets and product data for selected equipment.

3-2.1.2 Other Exterior Systems.

- Telecommunications (including voice, video and data) System – Identify point of connection into base system. Describe modifications, if required, to existing base system.
- Special Systems – Identify any special systems, such as Electronic Security Systems (ESS) or Cable Television (CATV). Describe how and where the facility will connect to the basewide Mass Notification System.
- Exterior Lighting Systems – Describe types of luminaires and illuminance values.
- Alternate Energy Sources – Describe alternate energy systems such as engine-generator sets, photovoltaic power systems, wind turbines, and fuel cells.
- Metering – Determine installation specific metering requirements as part of the electrical distribution system connection during design.
- Conductors – Include conductor type and number of conductors.
- Standards of Design – Describe pertinent standards of design, such as voltage drop and equipment ratings.
- Materials – Provide manufacturer's data sheets and product data for selected equipment.

3-2.1.3 Interior Distribution Systems.

Describe the electrical systems including the following: lighting systems; power systems; alternate energy systems, emergency lighting; emergency/standby power; grounding systems; telecommunications system; other systems such as television; physical and electronic security features such as ESS or TEMPEST. Refer to NSTISSI 7000, TEMPEST Countermeasures for Facilities, for TEMPEST criteria.

- a. Electrical Characteristics – Describe the electrical system to be provided and justify its selection. Indicate ANSI voltage designation, phase, and number of conductors.
- b. Switchgear and Switchboards – Provide specific design information for the following:
 - Nominal system voltage.
 - Short circuit ratings.
 - Maximum voltage ratings.

- Basic impulse level (BIL).
- Main bus ampacity.
- c. Estimated Electrical Loads – Provide a breakdown, by category, of the estimated loads (kVA). Include lighting, convenience outlet, mechanical equipment, special operating equipment, user equipment, and miscellaneous load categories.
- d. Wiring Methods – Indicate the type of wiring method, such as rigid conduit, electrical metallic tubing, cable tray, nonmetallic sheathed cable, and where proposed to use.
- e. Conductors – Indicate the type of conductors and insulation material such as CU, AL, THW, XHHW, and where proposed to use.
- f. Standards of Design – Describe the proposed standards of design, such as voltage drop, illuminance values, type of light sources, and energy conserving features.
- g. ASHRAE compliance – Describe the approach for compliance with UFC 1-200-02 and its ASHRAE 90.1 requirements.
- h. Special Systems – Describe the proposed type of systems. Indicate each system's function and the interrelationships between systems, when applicable. Identify government-furnished equipment, if any. Special systems include such systems as CATV, Closed Circuit Television (CCTV), Intercom, Sound, Nurse Call, Security, or Uninterruptible Power Supplies (UPS). Identify special security requirements. Identify special physical security requirements.
- i. Telecommunications Systems – Identify space required for telecommunication equipment, and size of incoming duct/conduit. Include documentation concerning telecommunications room sizes, to accommodate interface equipment provisions for multi-use systems (i.e. special use systems, such as voice, video, and data).
- j. Materials – Where appropriate, like for design build, provide manufacturer's data sheets and product data for selected equipment.

3-2.1.4 System Maintainability.

Design the system in a manner that facilitates safe periodic maintenance of the equipment in accordance with Section 2-1.8.

3-2.1.5 Instrumentation and Controls.

Coordinate all interfaces with instrumentation and control systems provided by other disciplines, and provide required connections, either empty conduits or power wiring as required. Normally, the designer for the discipline that is responsible for the process (such as electrical, mechanical, or civil) is also responsible for the instrumentation and controls design of that system.

3-2.2 Electrical Calculations – Overview.

The Designer of Record (DOR) is responsible for providing calculations (in accordance with the associated follow-on paragraphs) to verify proper design and operation of the facility to the point of connection to the existing electrical systems.

Note: There can be differences in how the required electrical analyses are handled, depending on whether the project is design-build or design-bid-build. Army projects might also use UFGS 26 05 73, Power System Studies, as the method for specifying requirements associated with the coordination study during the construction phase.

The DOR is also responsible for:

- Contacting and obtaining all utility data required to complete the relay coordination study from the respective Base Electric Utility Department or Private Utility Company including existing upstream protective device types and settings. The information needed for the electrical analysis depends on the point of connection to the primary distribution system and the scope of the project.
- Determining the different operational configurations. If the facility or system has various operational configurations (such as different transformer supplies, emergency generator operation, UPS bypass, or microgrid) or operational modes (such as normal parallel mode, transition-to-island mode, island mode, and reconnection mode), evaluate each possible operating configuration and each operational mode, and provide the results for each case.
- Providing analyses and calculations that are described fully, written clearly, and lead the reviewer through the design by stating all assumptions and design inputs. Computer printouts are acceptable only if accompanied by explanations to allow adequate independent review of calculation methods and results.

3-2.2.1 Electrical Analysis Software.

Most electrical-related calculations for significant projects will be completed with software tools; hand calculations are typically only acceptable for minor modifications to an existing system. For power systems analyses, coordinate with the base to determine if specific software tools are required for the analyses. Whenever software tools are used to perform analyses, provide the electronic software files with each submittal. Electronic software files must be in a format compatible with the analysis software used at the Government's facility. Before using any software tools, identify any base or service-specific limitations regarding which software packages can be used.

Note: The Navy Network is only able to utilize ETAP, SKM software modules and EasyPower for electrical analysis. If project calculations are done using any other software, they must also be provided in either ETAP, SKM or EasyPower so that they

are usable by Navy personnel on the Navy Network. The designer performing the calculations shall verify with the Navy which software package they are using at that facility and provide their database calculations to the Navy in that software database.

Note: For the Air Force, only EasyPower is certified in accordance with AFI 33-210 for use on standard desktop systems connected to the Air Force Global Information Grid and placed on the Air Force Evaluated/Approved Products List. Other software products can be used on standard desktop systems connected to the Air Force Global Information Grid after they have been certified in accordance with AFI 33-210 and placed on the Air Force Evaluated/Approved Products List.

3-2.2.2 Electrical Calculation Summary.

Provide calculations that include a complete analysis with supporting data. Address system arrangement; voltage selection; and major equipment selections including load analysis and equipment sizing calculations. Whenever sizing electrical equipment, such as transformers, breakers, or electric cables, provide calculations to demonstrate proper facility design. Provide the following calculations unless the Basis of Design clearly explains why a particular calculation type is not applicable:

- a. Load analysis.
- b. Short circuit analysis, including protective device interrupting rating.
- c. Protective device time-current coordination study.
- d. Arc flash analysis.
- e. Voltage drop.
- f. Motor starting analysis.
- g. Lighting.
- h. Underground structure design.
- i. Cable pulling tension.
- j. Directional Boring
- k. Sag, tension, and guying analysis.
- l. Cathodic protection calculation.
- m. Lightning protection analysis.
- n. CATV network loss calculations.
- o. ESS calculations.
- p. Alternate energy system calculations.
- q. Utility interactive systems and distributed resources island systems evaluation.
- r. ASHRAE 90.1 calculations.

Detailed requirements for each calculation item in the list are contained in the following paragraphs.

3-2.3 Load Analysis.

3-2.3.1 Preliminary Basis of Design.

- a. Load Analysis for Service Entrance Equipment, Including Feeders:
 - Complete a preliminary load analysis (Basis of Design). Base calculations on NFPA 70 and use load information provided in Appendix B or ASHRAE 90.1 as applicable. Use Appendix C to apply demand and load factors when sizing the service entrance transformer only. Do not apply these factors to distribution equipment downstream of the service entrance transformer.
- b. Load Analysis for Service Entrance Transformer:
 - Select appropriately sized transformer based on:
 - i. The standard available ratings and
 - ii. The calculated demand load which is connection to each transformer.
 - Apply the demand and diversity factors from Appendix C to the preliminary load analysis to determine the transformer size.
 - For building designs, do not exceed a service transformer size greater than 12 VA/square foot (130 VA/square meter) of facility gross floor area or 70% of the total connected load on installations served by transformer rated 300 kVA or greater. Any design calculations exceeding these requirements must be specifically approved by the technical reviewing authority.

Note: The above check is intended to serve as a simple confirmation that the facility transformer is not oversized.

- c. Load Analysis for Emergency/Standby Generator:
 - Provide sizing calculations including starting kVA.
 - Refer to UFC 3-540-01 for additional load analysis requirements, including the effect of UPS systems on generator sizing.
- d. Load Analysis for Alternate Energy Systems:
 - Provide maximum power calculations applicable to the type of alternate energy system. This includes:
 - i. DC systems, including 270 VDC charging systems.
 - ii. Frequency conversion equipment.
 - iii. Renewable energy systems.

- e. Load Analysis for Uninterruptible Power Supply (UPS):
 - Provide sizing calculations in accordance with UFC 3-520-01, section entitled “Stationary Batteries and Battery Chargers”.
- f. Load Analysis for utility interactive systems and distributed resource island systems (microgrids). Provide a load analysis in accordance with IEEE Std 1547.4 Clause 5. Include a system one-line diagram with system interconnection points. Evaluate historical demand profiles (real and reactive) and identify any large motor loads. Include in the load analysis a calculation of real and reactive power requirements in normal and island mode of operation.

Note: Microgrids are not included with all projects. When required by the project scope of work to install a new system or to incorporate a microgrid into an existing system, provide a complete description of the microgrid including its connection points to the system and how the system will operate.

- g. ASHRAE 90.1 calculations:
 - Power allowance for lighting.
 - If the design methodology requires additional receptacles to satisfy the ASHRAE 90.1 automatic receptacle control criteria, identify as a line item in the system load analysis.

3-2.3.2 Follow-On Submittals.

- a. Load Analysis for Service Entrance Equipment, Including Feeders:
 - Complete a load analysis (Basis of Design). Base calculations on NFPA criteria.
- b. Load Analysis for Service Entrance Transformer:
 - Apply the demand and diversity factors from Appendix C to the final total connected load analysis to determine the transformer size. For example, Diversity Factor - A distribution feeder serves 4 buildings, each has a peak demand of 25 KW. The feeder peak demand is equal to 80 KW. The diversity is equal to 80/100 or .8. Demand Factor - a residence having 12,000W of total connected load has a maximum demand load of 9,000W. The demand factor is $9,000/12,000 = 75\%$.
 - For building designs:
 - For all transformers, do not exceed a service transformer size greater than 12 VA/square foot (130 VA/square meter) of facility gross floor area.
 - For a transformer rated 300 kVA and larger, do not exceed a service transformer size of 70% of the total connected load.

- Validate that transformer size has not been increased by the design approach taken to comply with ASHRAE 90.1.

Any design calculations exceeding these requirements must be specifically approved by the Technical Reviewing Authority.

- c. Load Analysis for Emergency/Standby Generator:
 - Provide sizing calculations including starting kVA.
 - Refer to UFC 3-540-01 for additional load analysis requirements, including the effect of UPS systems on generator sizing.
- d. Load Analysis for Alternate Energy Systems:
 - Provide maximum power calculations applicable to the type of alternate energy system. Identify actual power delivered from source.
- e. Load Analysis for Uninterruptible Power Supply (UPS):
 - Provide sizing calculations in accordance with UFC 3-520-01, section entitled “Stationary Batteries and Battery Chargers”.
- f. Load Analysis for utility interactive systems and distributed resource island systems (microgrids) in accordance with the criteria provided in Section 3-2.3.1.f.
- g. ASHRAE 90.1 calculations in accordance with the criteria provided in Section 3-2.3.1.g.

3-2.3.3 Load Analysis Criteria.

Use the following additional criteria for the load analysis:

- Assign a “0%” demand factor for fire pump loads in demand calculations.
- Design underground service entrance distribution using commercially-available thermal analysis software based on Neher-McGrath or finite element methods. Assume a load factor of 100%.
- Size the service entrance conductors for a continuous load current not less than the ampacity of the main bus in the service entrance equipment. For example, provide conductors sized for 1200 amperes with 1200 ampere rated equipment which is protected with a 1000 ampere device. Listed conductor size adapters are acceptable. Design main service equipment to provide a minimum of approximately 15% combination of spare devices/space to accommodate future work. Include this 15% spare capacity in the demand load calculations for future or anticipated load growth.

Note: Consideration for spare device/space above 15% should be addressed during the scoping of the project.

- Select size of service entrance transformers based on the standard available ratings.

Note: This criterion does not apply to secondary substation transformers, dedicated site lighting transformers, etc.

For small systems 225 amps or less, or for small modifications to large systems, the load analysis can be performed manually using the above criteria. For larger systems, a load analysis using computer software tools is necessary to evaluate properly all of the possible facility modes of operation.

3-2.4 Short Circuit Analysis.

Complete a short circuit analysis in accordance with IEEE 3002.3 and include the following in the analysis:

- a. Include the utility system data as well as data for the distribution system. Contact the Contracting Officer or technical reviewing authority for the utility system data and available fault current on the primary side of medium voltage equipment. When accurate data does not exist, assume that maximum available fault exists, up to a possible infinite bus on the primary side of the upstream transformer, and design the system assuming such conditions.
- b. Calculate the available short circuit and ground fault currents at each bus. Incorporate any motor contribution in determining the momentary and interrupting ratings of the protective devices.
- c. Use a commercially available software program designed for the type of required analysis. Incorporate pertinent data and the rationale employed in developing the calculations in the introductory remarks of the study. Comply with IEEE C37.06, IEEE C37.13.1, or UL 489 criteria, as applicable, for equipment interrupting capability evaluations.
- d. Where diagrams will not fit on standard letter size paper, present the data determined by the short circuit study in a tabular format. Include the following:
 - Device identification
 - Operating voltage
 - Protective device
 - Device rating
 - Calculated short circuit current
- e. Coordinate the calculated short circuit current at the service entrance with the available fault current labeling required by NFPA 70 for the service entrance equipment (switchgear, switchboard, or panelboard).

3-2.5 Protective Device Time-Current Coordination Study.

3-2.5.1 Selective Coordination.

Design the electrical system such that any fault in the system will be preferentially isolated by the selective operation of only the overcurrent protective device closest to the faulted condition. If required by the contract, perform a coordination study at the design stage to establish the basis for the system design and to enable completion of an initial arc flash analysis. Provide a final coordination study based on the as-built configuration of the system. Identify locations where selective coordination is not achievable, such as with instantaneous trips on molded case circuit breakers.

The Designer of Record is responsible for the selective coordination of overcurrent protective devices, including protective relays and medium voltage protective devices, high side transformer protection for distribution transformers, main secondary breakers, and secondary feeder protective devices. Ensure coordination between the new equipment design and the existing distribution system.

Selective coordination shall not be required between two overcurrent devices located in series if no loads are connected in parallel with the downstream device.

Any permanently installed backup power source required by published DoD or agency-specific criteria shall be considered a legally required standby system or emergency system.

3-2.5.2 Required Time-Current Data.

The Designer of Record is responsible for ensuring that construction contract documents require the Contractor to submit the transformers' inrush current and damage curve and the manufacturer's published time-current curves for primary fuses, relays, main secondary breakers, and secondary feeder protective devices. This information is required during the submittal process. Using the time-current curve data, perform a coordination study in accordance with the following paragraphs to ensure that protective devices are properly coordinated.

3-2.5.3 Coordination Study.

If required by the contract, provide a complete coordination study that includes a system one-line diagram, short circuit and ground fault analysis, and protective coordination plots.

The Designer of Record is responsible for providing to the Contractor settings for relays, main secondary breakers, secondary feeder protective devices, and any other protective devices in the circuit. Base the final coordination study and the specified setting information on the as-built configuration.

3-2.5.4 One-Line Diagram(s).

Show on the one-line diagram all electrical equipment and wiring to be protected by the overcurrent devices including breakers and fuses. Multiple one-line diagrams may be used if required to clearly present all the required data. Also, show on the one-line diagram the following specific information:

- a. Calculated short circuit values and X/R ratios at the project utility point of connection.
- b. Breaker and fuse ratings.
- c. Transformer kVA and voltage ratings, percent impedance, and wiring connections.
- d. Identification and voltage at each bus.
- e. Identify feeder cable sizes and conduit sizes. Identify configuration such as 4-#2 AWG, 1-#4 AWG ground in 1-1/2" conduit. (Use worst case fill based on allowed materials.) Where limitations on materials and insulation are specifically required due to special environments, clearly identify this when applicable.

3-2.5.5 Coordination Curves.

Prepare the coordination curves to determine the required settings of protective devices to assure selective coordination. Graphically illustrate on a log-log scale that adequate time separation exists between series devices, including the utility company upstream devices where applicable. Plot the specific time-current characteristics of each protective device in such a manner that all applicable upstream devices will be clearly shown on one sheet. Include the following information on the coordination curves:

- a. Device identification.
- b. Voltage and current ratios for curves.
- c. 3-phase and 1-phase ANSI damage points for transformers directly fed from the switchgear.
- d. Minimum melt and total clearing curves for fuses.
- e. Cable damage curves.
- f. Transformer inrush points.
- g. Maximum short circuit current.

3-2.5.6 Settings.

Develop a table to summarize the settings selected for each protective device. Low voltage protective devices less than 225 amperes, unless adjustable trip, are not required to be included. Address all relays and relay functions. Include in the table the following:

- a. Device identification and breaker or load controlled.
- b. Relay CT ratios and electronic set point equivalents for relay tap, time dial, and instantaneous pickup points.
- c. Circuit breaker sensor rating.
- d. Fuse rating and type.
- e. Ground fault pickup and time delay.
- f. Differential relay settings.

3-2.5.7 Coordination Study Report.

Include the following in each coordination study report:

- a. A narrative describing the analyses performed, the methods used, and the desired method of coordinated protection of the power system.
- b. Descriptive and technical data for existing devices and new protective devices. Include the manufacturers' published data, nameplate data, and definition of the fixed or adjustable features of the existing or new protective devices.
- c. Documentation of the utility company data including system voltages, fault MVA, system X/R ratio, time-current characteristic curves, current transformer ratios, and protective device settings.
- d. Fully coordinated composite time-current characteristic curves to ensure coordinated power system protection between protective devices or equipment. Include recommended ratings and settings of all protective devices in tabulated form.
- e. Evaluation of the total feeder inrush current with respect to relay or circuit breaker overcurrent trip settings. Power restoration following an outage should not cause a feeder trip on overcurrent.

3-2.6 Arc Flash Analysis.

Complete an arc flash evaluation in accordance with NFPA 70E, IEEE C2 and IEEE Std 1584 (including Amendments 1 and 2), and IEEE Std 1584.1 as applicable.

Note: Nominal system voltages over 15 kV must follow IEEE C2 (NESC) instead of NFPA 70E and IEEE Std 1584.

Note: Provide PPE criteria in accordance with Chapter 4 of UFC 3-560-01.

Complete an arc flash evaluation on direct current (DC) systems analysis in accordance with NFPA 70E. Include the following:

- a. Description of the software used to perform the evaluation, including an explanation of software-specific user adjustable analysis settings that were used for the study.
- b. Scope of analysis. When switchgear, switchboards, and panelboards are equipped with main circuit breakers, provide both “Line Side” and “Bus Side” results for each item. If the facility or system has different operational configurations, such as different transformer supplies, emergency generator operation, or UPS bypass, evaluate each possible operating configuration and provide the arc flash results for each case. When equipment design includes dual protective device settings for the purpose of equipment maintenance (non-coordinated system), provide the arc flash result for that scenario. Summarize all data and include the worst-case results in terms of arc flash levels.
- c. Assumed working distance in feet. For low voltage systems, assume a working distance of 18 in. For medium voltage systems, assume a minimum working distance of 4 ft. For high voltage systems, assume a minimum working distance of 6 ft.
- d. For medium voltage and high voltage systems, credit can be taken for the associated distribution feeder circuit breaker as the upstream device if:
 - Existing circuit breakers – documented maintenance and testing of the circuit breaker and relay is less than five years old.
 - New circuit breakers – the circuit breaker and relay commissioning process confirm functionality in accordance with NETA ATS.
- e. For existing low voltage systems, credit can be taken for the main breaker as the upstream protection device if one of the following configurations apply:
 - The main breaker is located remotely (separate enclosure) from the feeder breakers.
 - The main breaker is located in its own sealed compartment, such as a switchgear.
- f. For existing low voltage systems, an upstream circuit breaker can be credited to clear the arcing fault if:
 - There is documented maintenance and testing for the circuit breaker.

Note: Maintenance confirms the functional capability and physical condition. Testing confirms that the circuit breaker can respond to and clearing an overcurrent event in accordance with its published time-current curves.

- Documented maintenance and testing is less than five years old.

- g. For new low voltage systems, an upstream circuit breaker can be credited to clear the arcing fault if the circuit breaker commissioning process confirms functionality of the trip unit in accordance with NETA ATS.
- h. Calculated energy in cal/cm² at each evaluated location. The design goal is to establish arc flash levels that result in 8 cal/cm² or less. Consider remote racking mechanisms to rack breakers in and out to limit personnel exposure to an arc flash event. Specifically identify locations where this energy level cannot be achieved, such as upstream of a main breaker (between the breaker and an upstream transformer) or downstream of UPS systems.
- i. Specified protective device settings to achieve the arc flash results. Reconcile arc flash protective device setting recommendations with the protective device time-current coordination study.
- j. List of work locations exceeding 40 cal/cm².

3-2.7 Voltage Drop.

The following voltage drop requirements apply to AC and DC constant voltage systems 1000V or less unless more stringent criteria apply. The following does not apply to constant current systems or distribution systems over 1000V. In situations where the voltage within a facility's distribution system is increased over this threshold, the voltage drop requirements shall restart assuming nominal voltage when transformed below the threshold.

400Hz systems must be designed for voltage drop in accordance with UFC 3-555-01N requirements.

If the phase conductor size is increased for voltage drop, increase the size of the equipment grounding conductor proportional to the circular mil increase of the phase conductor in accordance with NFPA 70 Section 250.122.

3-2.7.1 Permitted Voltage Drop.

The maximum voltage drop permitted must not exceed 5%. Unless stricter requirements apply as adopted by this or other UFCs, feeders and service conductors must be limited to 3% voltage drop and branch circuits must be limited to 3% voltage drop, with no greater than 5% total. The starting point for this calculation is defined below.

Calculation limits must be based on the cumulative amount of voltage drop seen at a given location in the distribution system from the start of calculation identified below, not on an individual basis by circuit.

3-2.7.2 General Voltage Drop Mitigation Strategies and Impacts.

Voltage drop can be mitigated through various strategies, including increasing conductor size, reducing the circuit's load, decreasing the conductor's length, decreasing conductor temperature, and improving power factor. When establishing distribution equipment placement within a facility, locate panelboards relatively central to the loads supplied to minimize circuit lengths. Likewise, routing the majority of the distribution at 480/277V and stepping down to 208/120V more locally to the loads served will yield a lower voltage drop to the end devices; this strategy needs to evaluate a balance between transformer and circuit costs, as well as requirements to submeter different load types when applicable.

Note increased conductor sizes will yield lower conductor resistances, lead to increased fault current values, and impact arc flash values at the equipment buses, potentially leading to protection coordination issues. Designers must ensure all conductor sizes are established prior to performing final fault current and arc flash calculations, and update safety calculations when modifying existing systems.

3-2.7.3 Voltage Drop Relationship with Utilization Voltage.

Voltage drop calculations focus on energy loss through conductors, and voltage drop contributes to utilization voltage for end users. However, voltage drop and utilization voltage, which is the actual voltage seen at end-use devices and equipment, are not synonymous. Devices and equipment have acceptable utilization voltage ranges within which operation can occur, the lower bound of which can be of a lower voltage than yielded by the maximum permitted voltage drop alone. Other system losses occur throughout the distribution system, most notably through transformers, and the voltage delivered by the utility service may deviate from the nominal voltage assumed in calculations. Transformer tap settings aid in providing appropriate downstream utilization voltage, however, the use of transformer taps does not negate energy losses incurred through conductor impedance voltage drop.

Design and construction personnel must remain cognizant of the utilization voltage requirements for the equipment and appliances served. Adjustments to the distribution system, such as the use of transformer taps and/or an increase in conductor sizes, must be performed accordingly to ensure proper utilization voltage is provided to the end use devices while simultaneously satisfying the voltage drop energy conservation requirements.

Practices used to boost utilization voltage at the load must not be used as a method to comply with voltage drop requirements.

3-2.7.4 Calculation Assumptions and Procedures.

3-2.7.4.1 Initial Voltage.

The use of service transformer taps must not be assumed to compensate for voltage drop on the service-entrance equipment side of the calculation start point. Calculations

must assume the nominal system voltage (i.e., 208V, 240V, 480V) is present at the location described for the calculation starting point.

3-2.7.4.2 Starting Point.

Voltage drop calculations must start at the point of government ownership (i.e., transformer, disconnect switch, meter cabinet, or similar). Where the government owns the exterior distribution upstream of the service transformer, the calculation must start at the service transformer secondary lugs. Where the facility is without a service transformer and supplied by independent generator or energy storage system, the calculation must start at such power supply's output terminals.

3-2.7.4.3 Load Estimations.

3-2.7.4.3.1 Capacity.

The capacity must be 100% of a circuit breaker or fuse device's nominal rating (e.g., 100A standard (80%) devices and 100A continuous (100%) devices are both considered 100A capacity) for voltage drop calculation purposes. See UFC 3-520-01 regarding Adjustable-Trip Devices.

3-2.7.4.3.2 Feeder Loads.

Size feeders to accommodate the maximum permitted load based on the circuit ampacity. Exceptions to this are as follows:

- a. **Transformer Feeders.** Per ANSI C57.96, transformers complying with the ANSI standard are designed for continuous operation at the specified temperature rise for normal life expectancy at the rated kVA. The rated kVA may be different than the nameplate or nominal kVA value based upon insulation temperature rating, ambient temperature, altitude, and other operating conditions.

For voltage drop purposes, a transformer's secondary feeders must assume a load equivalent to the transformer's nominal output rating.

For voltage drop purposes, a transformer's primary feeders must assume the same load as identified above for the secondary feeders PLUS 6% transformer loss load.

- b. **Motor Feeders.** Motor overcurrent protection is located at the overloads and NFPA 70 categorizes the circuits from the circuit breakers to the overcurrent protection as feeders. As on transformer primary circuits, circuit breakers are sized to account for inrush. Utilize the circuit's total full-load amps (FLA) based on NFPA 70 Article 430 tables for voltage drop calculations. Additionally, this circuit must be considered a "branch circuit" for voltage drop compliance purposes only.

Fire pumps must comply with the voltage drop requirements identified in NFPA 70 Article 695 in lieu of the limits stated in this section.

- c. **Air-Conditioning and Refrigerating Equipment Feeders.** The voltage drop load must be the rated-load current or full-load current marked on the nameplate as identified in NFPA 70 Article 440. Additionally, this circuit must be considered a “branch circuit” for voltage drop compliance purposes only.
- d. **Variable Frequency Drives/Adjustable Speed Drive Feeders.** Feeders to variable frequency drives, adjustable speed drives, and similar must be sized for voltage drop based on the drive’s maximum input current, including any drive losses. Additionally, this circuit must be considered a “branch circuit” for voltage drop compliance purposes only.
- e. **Other Feeders Directly Supplying Motor-Based Equipment.** Where NFPA 70 categorizes conductors as feeders, but the conductors supply dedicated motor-based equipment or equipment assemblies such as cranes and elevators, the voltage drop calculation load must be the total FLA. Application-specific NFPA 70 demand factors may be applied to the loads when used for voltage drop calculations. Additionally, this circuit must be considered a “branch circuit” for voltage drop compliance purposes only.

3-2.7.4.3.3 Branch Circuit Loads.

- a. **Lighting Circuits.** Lighting circuits must utilize the total full load of all luminaire and non-luminaire devices connected. Where the lighting circuit contains non-luminaire components such as room controllers or power packs, ensure such loads are captured.
- b. **Receptacle Circuits.** Receptacle circuits (including circuits where a dedicated receptacle is provided for a single device, appliance, or equipment) must use 80% of the circuit’s capacity for voltage drop calculations.
- c. **Systems Furniture Circuits.** Systems furniture circuits must use 80% of the circuit’s capacity for voltage drop calculations.
- d. **Hard-Wired Appliance and Other Non-Receptacle Circuits.** Hard-wired appliance and other non-receptacle circuits must utilize the total connected load on the circuit for voltage drop calculations.

3-2.7.4.4 Circuit Lengths.

3-2.7.4.4.1 Methods.

See UFC 3-520-01 for routing estimation instructions, and utilize the applicable method as described and assigned below.

- a. **End-of-Line Method.** Loads on circuits must be at the end of the circuit for voltage drop calculations unless otherwise indicated below.
- b. **Point-to-Point Method.** Calculate the load contributions to voltage drop as a function of the load experienced for a given portion of the circuit except as identified in the subsequent entries of this section. That is, the entire load on the circuit is experienced to the first device, be it a load, splicing/junction point, etc. Beyond that point, the load is diminished for the next series or parallel lengths, and only those loads contribute to the voltage dropped in the associated circuit length.

The totality of the voltage dropped on any given path must be evaluated in determining a satisfactory conductor size (i.e., the path to one end device may experience less voltage drop than the path to a different end device), and the more severe condition in a comparison of multiple paths must be used for the entire circuit size.

3-2.7.4.4.2 Feeders.

The entire feeder conductor lengths from the start of calculation described above to the last circuit breaker or fuse for a given portion of the distribution system must be used in the voltage drop calculation using the End-of-Line method.

3-2.7.4.4.3 Branch Circuits.

As with feeder conductors, the entire length of the branch circuit conductors (End-of-Line) must be used in the calculation except as follows for the purposes of the voltage drop load location:

- a. **Lighting Circuits.** Lighting circuits may use the Point-to-Point Method. Where the lighting circuit contains non-luminaire components such as room controllers, power packs, or other line-voltage control devices, ensure the lengths used and loads associated used in the voltage drop calculation capture these portions of the circuit, including travelers between three- and four-way switches.
- b. **Receptacle Circuits.** The load identified above must be at the farthest receptacle (End-of-Line) as routed through other receptacles, junction boxes, control devices, etc.
- c. **Systems Furniture Circuits.** The load identified above must be at the point of connection to the assembly (End-of-Line) as routed through junction boxes, control devices, etc., prior to the point of systems furniture connection.
- d. **Hard-Wired Appliances and Other Non-Receptacle Circuits.** Hard-wired appliances and other non-receptacle circuits may use the Point-to-Point Method.

3-2.7.4.5 Additional Calculation Considerations.

3-2.7.4.5.1 Circuit Breakers in Series for Singular Loads or Set of Receptacles.

In situations where a circuit supplies a singular load or set of receptacles but is provided with an additional overcurrent protective device local to the load, the two portions of the distribution system may collectively be considered as part of the “branch circuit” for voltage drop calculations. For example, if an interior panelboard circuit breaker supplies an exterior pedestal-mounted receptacle with a local circuit breaker, the combined length of the circuits from the panelboard circuit breaker to the pedestal circuit breaker and from the pedestal circuit breaker to the receptacle may be sized using the branch circuit requirements for voltage drop (rather than the circuit from the panelboard circuit breaker to the pedestal circuit breaker being considered part of the feeder portion of the distribution system).

3-2.7.4.5.2 Branch Circuits Containing a Mix of Load Types.

Use the worst-case load assignment for the voltage drop calculation. Where portions of the circuit are distinguishable by load type, the worst-case voltage drop calculation may be performed for each full path from source to end device and the worst-case of the comparative results must be used.

For example, a branch circuit is routed to a junction box, where the circuit is split into separate circuit paths (‘A’) for a set of receptacles and (‘B’) for a set of luminaires. The entirety of the circuit load must be included from the source to the divergent point at the junction box; include the voltage drop to this point in the sizing for the comparative calculations. Then use the sizing results from the comparative calculations between ‘A’ and ‘B’ to establish a circuit size.

3-2.7.4.5.3 Voltage Drop through Transformers.

Voltage drop through transformers due to transformer losses for design calculation purposes must be zero. When modeling, configure transformers such that the voltage drop percentages relative to the values identified in section “Initial Voltage” above on the transformer primary and secondary buses match. That is, if the totality of the voltage dropped to the transformer primary terminations is, for example, 1.50% of the nominal system primary voltage, the calculation for the start of the conductors at the transformer secondary lugs must be at 1.50% of the nominal system secondary voltage. The aforementioned load associated with transformer losses are to be accounted for in the voltage drop calculations for the distribution system upstream of the transformer.

Voltage drop mitigation measures must be through conductor size increases only, and through strategic selection of voltage systems and locations of transformation equipment.

Transformer taps must not be used in voltage drop design calculations and must be used for field adjustments only, including to account for voltage lost through the transformer or longer conductor routing lengths than estimated in design. Note the

output voltage of a transformer will drop as the load increases or the power factor decreases.

3-2.7.4.5.4 Voltage Drop Allowances Addressed by Industry Standards.

For specific applications whereby a published industry standard establishes a voltage tolerance wider than the requirements of this section, the requirements of this section will end at the point at which the facility distribution system interfaces with the specific appliance, equipment, or similar system. For example, the voltage drop limits provided by this section must be met for crane systems to the point of connection at the runway electrification system, however, the voltage drop experienced through the runway and subsequent conduction paths to the eventual loads may adhere to CMAA-70 instead.

Similarly, the additional voltage drop experienced through appliance cord and plug connections are not covered under this section's requirements, which end at the receptacle connection point.

3-2.7.4.6 Power Factor.

For applications where power factor is known or can be easily estimated based on industry standards or approved sole-source equipment, utilize such information. The following are typical power factors and must be used as estimations where the specific power factor is unknown:

	208/120V	480/277V
Fluorescent Lighting	0.95	0.95
Compact Fluorescent Lighting (hardwired)	0.90	0.90
Compact Fluorescent Lighting (GU-24)	0.50	0.30
LED Lighting	0.90	0.90
Incandescent Lighting	1.00	---
High-Intensity Discharge Lighting	0.90	0.90
HVAC Package Units	0.85	0.90
Other Motors Less than 5HP	0.80	0.80
Other Motors Greater than or Equal to 5HP	0.85	0.85
Electric Resistance Heating (including Hot Water)	1.00	1.00
Kitchen Equipment	0.90	0.90
Receptacles	0.85	0.85
Other	0.85	0.85

Table adapted from California Title 24.

Unity power factor must not be used for loads other than electric resistance heating and incandescent lighting.

3-2.8 Motor Starting.

Account for both starting and running current in motor calculations.

Refer to IEEE C37.96 for calculating motor inrush and how to place the knee point from starting to running on a Time Current Curve.

3-2.9 Lighting.

Provide calculations for interior and exterior lighting systems in accordance with UFC 3-530-01.

3-2.10 Underground Structures Design.

Provide sizing and cable bending radius calculations for underground structures (manholes and handholes) with cable sizing exceeding 500 kcmil. Verify design requirements of UFC 3-550-01 are met. Coordinate with the Activity on the naming convention for underground structure identification on the drawings.

3-2.11 Cable Pulling Tension Calculations.

Provide cable pulling tension and sidewall pressure calculations for medium voltage cable in conduit. Compare the calculations to the rating of the cable.

3-2.12 Calculations for Directional Boring.

Provide calculations in accordance with UFC 3-550-01, Appendix B.

3-2.13 Sag, Tension, and Guying Analysis.

Provide calculations in accordance with UFC 3-550-01.

Crane trolley contact conductors are exempted from this requirement due to excessive enveloping of the conductor.

3-2.14 Cathodic Protection Calculations.

Provide calculations in accordance with UFC 3-570-01.

3-2.15 Lightning Protection Calculations.

Provide a lightning risk assessment in accordance with NFPA 780 Annex L and document the required level of protection.

If lightning protection is a design requirement, provide a lightning protection system in accordance with UFC 3-575-01. Provide side flash calculations as required by NFPA 780. Provide calculations for alternative grounding methods when required by the design.

3-2.16 ESS Calculations.

Provide calculations in accordance with UFC 4-021-02.

3-2.17 Renewable Energy System Calculations.

Provide calculations for renewable energy system project requirements. As a minimum, incorporate the requirements of criteria under development in accordance with Section 2-1.8. Calculations can vary with the types of renewable energy system, but typically include:

- Predicted power generation – kW and kVAR.
- Predicted energy production – kWh per year.
- IEEE Std 1547 interface compliance.
- Voltage drop.
- Ampacity requirements.
- Site orientation and safety considerations, including glare analysis for photovoltaic systems.
- Electrical protection and coordination.

3-3 DRAWING REQUIREMENTS.

Provide adequate plans, including demolition, existing conditions, and new work, legends, details, and diagrams to clearly define the work to be accomplished. Coordinate construction drawings and specifications; show information only once to avoid conflicts. For the Navy, additionally comply with FC 1-300-09N for specific drawing requirements and drawing phases.

Utilize electrical design “Best Practices Information” located at <https://www.wbdg.org/dod/supp-tech-documents> to facilitate drawing requirements and related equipment detail required by the remaining paragraphs of this UFC.

Provide a General Note at the beginning of the Electrical Drawings clarifying the work to be accomplished. The following note is required unless directed or approved by the government:

“ELECTRICAL WORK AND MATERIAL IS NEW AND PROVIDED BY THE CONTRACTOR UNLESS INDICATED OTHERWISE”.

- a. Arrangement. Arrange the Electrical Drawings in accordance with the National CAD standards at <https://www.nationalcadstandard.org/ncs6/>. Provide drawings that are clear and consistent in presentation and format. Follow the NFPA 70 Metric Designations (mm) and Trade Sizes (in) for conduit.
- b. Multiple Conduit/Cable Runs. To avoid misinterpretation as to the quantity of cables and conduit required in multiple conduit and cable runs, use one of the following acceptable descriptions:

- Acceptable: Two 4-inch conduits, each containing four 500 kcmil and one #2 Gnd.
- Acceptable: Two 4-inch conduits, each with four 500 kcmil and one #2 Gnd
- Acceptable: Two 4-inch conduits, with four 500 kcmil and one #2 Gnd in each conduit
- Unacceptable: Two sets of four 500 kcmil and one #2 Gnd in 4-inch conduit
- Unacceptable: Parallel Service: Four 500 kcmil and one #2 Gnd in 4-inch conduit

3-3.1 Legends and Abbreviations.

Define all symbols used in the drawings in the legend. Locate legend on the first electrical sheet using multiple legends where required and identifying the specific use of each legend. Use different legends for new and existing work. Avoid using composite legends that include all symbols but fail to indicate which symbols are to be used on which drawings.

Refer to electrical technical paper TSEWG TP-12: Appendices for typical illustrations of how to properly display legends on the contract drawings. Refer to Appendix A for more information.

3-3.2 Site Plans.

Show utility point of common coupling to the base power and telecommunications systems on the site plan. Provide explicit direction on method of entering existing manholes. Provide all details including composition of duct banks and depth and configurations of the duct banks.

3-3.2.1 Coordination with Other Utilities.

Provide Electrical Site Plans that are separate and distinct from other utility site plans. Include with the electrical drawings. Electrical and civil site plans may be combined only when the project requires minor utility work. Coordinate with the electrical engineering reviewer before combining the electrical and civil site plans.

Provide the orientation of electrical drawings consistently with the civil drawings. In addition, provide the orientation of partial building or site plans identical to the orientation of the larger plan from which the partial was taken. Indicate the exact title of each detail, partial plan or elevation as identified on the cross-referenced sheet.

3-3.2.2 Overhead Distribution.

For overhead distribution use a separate symbol for each individual circuit; define each circuit by voltage level as well as number, size, and type of conductors. Coordinate

guying and conductor sag information shown on the drawings with that shown in the specifications.

3-3.2.3 Pole Details.

Indicate overhead distribution pole details on the drawings. Identify pole number assignment consistent with installation standards on the site plan and require pole identifier number to be installed on pole matching installation standard.

3-3.2.3.1 Format.

NAVFAC pole details are available in Adobe PDF format and in AutoCAD format on the WBDG website at <https://www.wbdg.org/dod/ufgs/forms-graphics-tables>.

Provide details in situations where an applicable pole detail has not been developed. Designer developed details must contain the same level of detail equivalent to the NAVFAC pole details and include material requirements.

Review the information contained on Details OH-1.1 through OH-1.5a for examples of how to show overhead distribution work. Do not describe proposed work by referencing sketch numbers instead of pole detail designation symbols. Do not use pole detail designation symbols to describe existing facilities to be removed. To maintain the integrity of the pole details, do not modify pole details; include any required exceptions or modifications as supplemental information with the pole detail designation symbols. When using pole details, place a note referencing the pole detail designation symbols (like the following) on the drawings:

“XFB, 15FR3-N are pole detail designation symbols. Refer to Sketches OH-1.1 through OH-41 on Sheets [TBD] for an explanation of the use and description of equipment provided by these symbols.”

3-3.2.3.2 Conductor Sag.

Indicate conductor initial sag values. Provide initial sag values at ambient temperatures in 18 degrees F (10 degrees C) increments for a temperature range, which includes the outside summer and winter design temperature values. Clearly indicate each different calculated ruling span on the plans and provide initial sag for one span in the calculated ruling span.

3-3.2.3.3 Fusing.

Provide appropriate symbol and detail indicating the use of backup current limiting fuses with the device being protected. Indicate the fuse type and ampere rating as well as the voltage rating and current designation of the backup current limiting fuse.

3-3.2.4 Transformer Details.

Indicate transformer details on the drawings. Transformer details are available in a PDF format and an AutoCAD format on the WBDG website at <https://www.wbdg.org/dod/ufigs/forms-graphics-tables>.

3-3.2.4.1 Descriptive Information.

Provide the following transformer descriptive information:

- Transformer type (e.g., pad-mounted, pole mounted, station type, unit-sub)
- kVA, single or three phase
- Voltage ratings per IEEE C57.12.00 (e.g., 11.5KV – 208Y/120 volts)
- Primary and secondary connection (when using single-phase units for three-phase service; specifically indicate how the units are to be connected, i.e., connect delta-wye grounded for 208Y/120-volt secondary service)

3-3.2.4.2 Surge Arresters and Fused Cutouts.

Include the following information for surge arresters and fused cutouts:

- Surge arrester kV rating.
- Cutout kV, continuous ampere, and interrupting ampere rating.
- Fuse link type and ampere rating.

3-3.2.5 Underground Distribution.

3-3.2.5.1 Required Information.

Profiles may be required for ductbank runs. Discuss profile requirements with the electrical reviewer. Indicate structure (manhole and handhole) tops, ductbank elevations, slopes, and diameters. Coordinate structure numbers with plan sheets. Show and label all crossing utility lines, both existing and new. If depths of existing utilities are unknown, indicate the horizontal location of the utility and indicate the vertical location with a line representing the anticipated range of elevations where the utility will be found in the field. Indicate the method of new utility installation routing above or below conflicts. Notes can be used to identify parts.

Provide cable/ductbank information indicating cable identification, description, conduit size, and remarks for any special instructions. Where four or more conduits are to be installed, provide in schedule format. For smaller applications, schedule or notational conveyance is acceptable.

3-3.2.5.2 Detail Drawings.

Provide manhole foldout details or exploded views for all multiple-circuit primary systems and all primary systems requiring splices. Indicate the entrance of all conduits and the routing of all conductors in the manholes.

Manhole details are available in Adobe PDF format and in AutoCAD format on the WBDG website at <https://www.wbdg.org/dod/ufgs/forms-graphics-tables>.

3-3.3 Demolition Plans.

3-3.3.1 Required Information.

Provide “Demolition” plans separate and distinct from “New Work” plans, except where only minor demolition work is required. Clearly show what is to be demolished, at an appropriate scale. Indicate the beginning and ending points of circuit removals.

For modification of or additions to existing equipment, provide the manufacturer’s name and other pertinent manufacturer’s identification (e.g., serial number, model number, style, and any other manufacturer’s identifying markings).

3-3.3.2 Demolition Sequence.

Provide a sequence of demolition; if necessary, include any known requirement for continuous operation and limited shutdown requirements. Identify these in the special scheduling paragraphs of the specifications.

3-3.3.3 Lighting Demolition.

Indicate the quantity of lighting ballasts that contain PCBs and the quantity of lamps that contain mercury.

3-3.4 Lighting Plans and Details.

Do not show lighting and power on the same floor plan, unless the scale of the plan is 1:50 ($\frac{1}{4}$ in = 1 ft – 0 in) or larger. "Provide a photometric layout plan as an appendix to the design analysis. The photometric layout plan may also be a for-information-only (FIO) drawing but may not be a contract drawing.

Provide luminaire (lighting fixture) details, separate luminaire schedule, controls, and control strategies for each space. Details and a luminaire schedule are available in Adobe PDF format and in AutoCAD format on the WBDG website at <https://www.wbdg.org/dod/ufgs/forms-graphics-tables>. To maintain the integrity of the details, do not modify details; make any required exceptions or modifications in the remark’s column of the luminaires schedule and not on the details themselves. Provide applicable luminaires type symbol(s) with each luminaire sketch/detail. When using luminaire(s) not included in the database, detail the luminaire(s) on the drawings providing the following minimum information:

- Luminaire type (e.g., high bay, fluorescent, industrial, downlight, roadway type, floodlight).
- Physical construction including housing material and fabrication method, description of lens, reflector, refractor.
- Electrical data including number of lamps, lamp type, ballast data, operating voltage.
- Mounting (surface, suspended, flush) and mounting height.
- Special characteristics such as wet label, specific hazardous classification, or air handling.

3-3.5 Power Plans.

Show all power requirements and points of connections. Specifically identify each piece of equipment including HVAC and mechanical equipment (e.g., unit heater No. 1, unit heater No. 2).

Typical illustrations showing proper methods for displaying equipment on the contract drawings are provided in a PDF format within the electrical technical paper TSEWG TP-12: Appendices. Refer to Appendix A for more information.

3-3.6 Telecommunication Plans.

Show locations of voice and data outlets in each room, closets, and equipment spaces. Detail all outlet, cable tray, backboard or distribution frames, and grounding bus bars.

Note: Power and telecommunication systems may be shown on the same drawings provided the design is small, the electrical designer and the telecommunications registered communications distribution designer (RCDD) are the same person, and combining the drawings is approved by the Contracting Officer or technical reviewing authority.

For larger designs where power and telecommunications plans are not shown on the same drawings, provide telecommunications drawings stamped by an RCDD. Refer to UFC 3-580-01 for telecommunications requirements.

3-3.7 Grounding Plan.

Provide grounding plans and details at an appropriate scale.

3-3.8 Roof Plan.

When roof mounted equipment, including HVAC equipment, cannot be adequately shown on the Power Plan, provide an appropriately scaled roof plan.

3-3.9 Lightning Protection Plan.

Provide lightning protection plan and details at an appropriate scale. Indicate locations and number of system components required. Show air terminal installation details, roof and wall penetration details, and details to show concealed components of the system.

Coordinate roof and wall penetrations with other disciplines to ensure that the integrity of the facility envelope is not compromised.

3-3.10 Hazardous Location Plan.

Provide on the drawings the boundaries and classifications of all hazardous locations in accordance with NFPA 70.

3-3.11 Power One-Line/Riser Diagrams.

Provide a power one-line (single-line) diagram for:

- Medium-voltage distribution systems, including substations and switching stations.
- Systems involving generation, either low voltage or medium voltage.
- Building switchgear, switchboards, and main distribution panels (MDPs).

3-3.11.1 Content and Format.

The one-line diagram must show all components (including metering and protective relaying). Indicate sizes of bus, feeders and conduits. Show connections of transformers, PTs, CTs, and capacitors on the one-line diagram by means of the proper symbol. Show potential and current transformer ratios. Indicate relay quantity and function (overcurrent, voltage, differential) using ANSI designation numbers.

On most facility-related projects, it is acceptable to combine the one-line diagram with a riser diagram. The one-line diagram would begin with the medium voltage system and continue through the transformer up to and including the main breaker and feeder breakers within the MDP. Sub-panels beyond the MDP may be shown in the riser diagram format.

3-3.11.2 Electrical Equipment.

Indicate kV ratings for surge arresters, and kV and ampere rating for cutouts. Indicate fuse link type and ampere rating. For capacitors indicate kVAR per unit, number of units per bank, voltage (voltage rating of units, not the system voltage), phase (e.g., three-phase or single-phase units), fuse size, and fuse type.

3-3.11.3 Transformer Information.

Show the following on the one-line diagram when a transformer is indicated, as applicable.

- Primary switches.
- Wye or delta connection.
- Loadbreak elbows.
- Lightning arresters.
- kVA rating.
- Rated voltage (primary & secondary).
- Transformer identification number.
- Industry standard impedance.
- Meter type.
- CT and PT sizes.
- Fuse sizes.

Show all pertinent transformer information on the one-line diagram as opposed to the specifications. Items that are common to all transformers can be indicated by notes on the one-line diagram if a typical detail drawing is provided.

3-3.11.4 Pad-Mounted Switchgear Information.

Show the following on the one-line diagram when pad-mounted switchgear is indicated:

- Spare ways (cubicles).
- Protective devices.
- Loadbreak elbows.
- Switch identification number.

3-3.11.5 Primary Distribution.

Show the following on the one-line diagram when a new primary is indicated:

- In-line splices in manholes.
- Normally open points.
- Number and sizes of phase, neutral and ground cables.
- Conduit sizes.

3-3.11.6 One-Line Diagram for Demolition.

If there is demolition involved or work is to be done to existing equipment, provide an existing one-line diagram showing the current arrangement of the gear and then show a new one-line diagram indicating by line weights what is existing or new.

3-3.11.7 Format.

Ensure that information shown on the one-line diagram is not duplicated elsewhere in the construction package, as this will likely cause conflicts if changes are necessary. Indicate on the electrical legend the exact nomenclature used to indicate conductor and conduit sizing. Provide a schedule for feeder runs. Provide medium voltage one-line diagrams for stations and distribution systems that have a geographic affiliation to the actual constructed distribution system.

Typical illustrations showing proper methods for displaying one-line and power riser diagrams on the contract drawings are provided in a PDF format within the electrical technical paper TSEWG TP-12: Appendices. Refer to Appendix A for more information.

3-3.12 Telecommunications Riser Diagram.

Clearly indicate service entrance cable and duct, entrance protector assemblies, and connections to existing outside cable plant. Include the following:

- Cross-connects. Indicate by notation that voice and data cables terminate in separate fields. Indicate method of cross connecting – patch panel or connector block.
- Telecommunications outlets, including room numbers.
- Cable for building backbone and horizontal distribution system.
- Pathway, including conduit and cable tray for backbone and horizontal distribution system.
- Telecommunications grounding system.

3-3.13 Intercommunication/Paging Riser Diagram.

Show power source, master station with associated equipment, speakers, and outlets. Include room numbers, wiring/conduit between components.

3-3.14 Fire Alarm Riser Diagram.

If required, fire alarm riser diagrams, including mass notification system, will be provided by the fire protection engineer.

3-3.15 Special Systems Riser Diagrams.

Provide other riser diagrams like those developed for telecommunications or intercommunication/paging.

3-3.16 Schedules and Elevations.

Provide elevations, sections, and details to clearly identify space constraints, unique conditions, design intent, or to ensure a specific method is implemented.

3-3.16.1 Panelboards.

Provide schedules for all panelboards. Provide the panelboard schedule reflecting the actual circuit breaker and bus arrangement. Include the following:

- Panelboard designation and location (i.e. room number).
- Voltage, phase, frequency, number of poles, and minimum interrupting rating.
- Main amperes indicating main breakers or lugs only.
- Surface or flush mounting.
- Circuit number, wire size, breaker trip, connected load, and identification of load associated with each branch or feeder. Provide the specific identification of load. For example, do not merely indicate "Lighting," but rather "Lighting, Room 102" for the directory marking.
- Total connected load (calculated load) including demand factors of all circuits.
- Any special breaker requirements such as GFCI, AFCI, SWD, adjustable trip, 100% rated.

Note: many manufacturers require minimum 400A panel frames for 100% breakers to be used.

- Neutral bus size (100% or 200%).
- See UFC 3-520-01 for additional values to be included in panelboard schedules and drawings.

Additionally, consider the following:

- Other conductor sizing factors specific to a given circuit such as anticipated ambient temperature on the assumed routing path, whether the load is nonlinear, and the number of current-carrying conductors for purposes of re-sizing should circuits be consolidated into a common raceway during construction.

Show all circuiting (identifying conduit and wiring back to specific panels but not identifying the exact routing required during construction) on the design drawings exactly as they are to be installed.

3-3.16.2 Switchboards and Switchgear.

Provide plan and elevation or isometric drawings for switchboards and switchgear, showing compartments, their intended use, and instruments, relays, and controls. Clearly show contents of all sections including whether breakers are individually, or group mounted. Indicate that switchboards and switchgear are mounted on 4 in (100 mm) elevated concrete pads. Coordinate design of pad with structural engineer.

3-3.16.3 Motor Control Centers.

Provide plan and elevation or isometric drawings for Motor Control Centers (MCCs) identifying compartments. Provide schedule listing each compartment. Include on the schedule (for each compartment) the description of load, load in amperes, load in horsepower, NEMA size and type of starter, breaker size, conductor and conduit size, control devices, and other special requirements.

- Indicate, on plans or in specifications, enclosure type, bus rating, bus material, bus bracing, NEMA class and wiring type, service voltage, control voltage and source, and top or bottom feed.
- Indicate on the drawings that MCCs are mounted on 4 in (100 mm) elevated concrete pads. Coordinate design of pad with structural engineer.
- Provide elevation of control panels, indicating front panel devices, such as indicator lights, pushbuttons, gauges, and switches.

3-3.17 Details/Diagrams.

Detail all telecommunications outlets, cable tray, and backboard/distribution frames. Provide elevations of pertinent communication room walls. Indicate additional details as required. Provide a junction box detail on the drawings showing the interface between the Systems Furniture wiring harness and the branch circuit wiring.

3-3.18 Grounding Diagrams.

Provide grounding diagrams with explicit grounding and grounded conductor requirements beginning with the medium-voltage system and continuing through the transformer up to and including the Service entrance equipment, step down transformers, sub-panels, and telecommunications systems grounding.

The service entrance grounding electrode systems and interconnections with other system grounding electrodes must be clearly shown and identified on the grounding plan. The main bonding jumper connection must be indicated and system bonding jumper connections for separately derived systems must be clearly indicated. Automatic Transfer switches must be identified indicating 3-pole design for single-phase systems

and 4-pole design for three-phase systems. Coordinate this UFC with TSEWG TP-19 and clarify when ATS with unswitched neutral be used in lieu of ATS with switched neutral. Typical illustrations showing proper methods for displaying grounding diagrams on the contract drawings are provided in a PDF format within the electrical technical paper TSEWG TP-12: Appendices. Refer to Appendix A for more information.

3-3.19 Cathodic Protection Plans and Details.

Provide cathodic protection plans and details at appropriate scales. Indicate on the drawing the location of all rectifiers, anode beds, structures, elevators, and overhead cranes protected by cathodic protection system(s). Include all structures, elevators, and overhead cranes that may be affected by stray current corrosion because of cathodic protection of the specific structure within the affected area of cathodic protection. A NACE-certified Cathodic Protection Specialist must prepare or review cathodic protection design. Follow the requirements of UFC 3-570-01.

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APPENDIX A TRI-SERVICE ELECTRICAL WORKING GROUP TECHNICAL PAPERS

The Tri-Service Electrical Working Group (TSEWG) has developed technical white papers to provide additional information on certain topics. Some of these papers contain information that was provided in earlier versions of the UFCs, which was considered important to maintain for reference. The following white papers are located at <https://www.wbdg.org/dod/supp-tech-documents>:

- **TP-01: Electrical Calculation Examples** – provides example calculations for a variety of electrical equipment.
- **TP-02: Capacitors for Power Factor Correction** – provides information regarding capacitor application, sizing, and design.
- **TP-03: Surge Protector Performance and Evaluation Criteria** – provides information for low voltage surge protection.
- **TP-04: Stationary Battery and Charger Sizing** – provides different sizing techniques for stationary applications.
- **TP-05: Interior Transformer Ratings and Installation** – discusses transformer application, rating, and installation criteria.
- **TP-06: Low-Voltage Breaker Interrupting Ratings** – explains how low-voltage circuit breakers are rated and tested.
- **TP-07: Protection System Design** – provides electrical analysis criteria for relays, fuses, and circuit breakers.
- **TP-08: Electrical Equipment Enclosures and Hazardous Locations** – provides NEMA and NFPA guidance regarding enclosure designs and hazardous location classifications.
- **TP-09: Automatic Transfer Equipment** – provides information regarding automatic transfer switch application and design.
- **TP-10: Arc Flash Levels for Fused Voltage Inputs to Electricity Meters** – provides an arc flash analysis for arcing faults downstream of protective fuses on an electricity meter.
- **TP-11: UFC 3-500-10N Best Practices** – UFC 3-500-10N was developed by NAVFAC and was superseded by the initial issue of UFC 3-501-01. TP-11 provides the best practices information that was contained in UFC 3-500-10N.
- **TP-12: UFC 3-500-10N Appendices** – UFC 3-500-10N was developed by NAVFAC and was superseded by the initial issue of UFC 3-501-01. TP-12 provides appendices that were not included in UFC 3-501-01.
- **TP-13: UFC 3-501-03N Load Demand Analyses** – UFC 3-501-03N, Electrical Engineering Preliminary Considerations, was superseded by the initial issue of UFC 3-501-01. UFC 3-501-03N contained in its entirety MIL-HDBK 1004/1, Electrical Engineering Preliminary Design

Considerations. TP-13 was issued to retain the load demand analysis information originally contained in MIL-HDBK 1004/1.

- **TP-14.** Reserved
- **TP-15: Arc Flash Calculations and Detailed Arc Flash Warning Labels**
– NFPA 70E requires a detailed arc flash warning label that specifies either the available incident energy in cal/cm² or the required level of personal protective equipment (PPE) that must be worn at a particular work location. TP-15 explains why detailed arc flash warning labels might be inappropriate for many military installations.

APPENDIX B DESIGN DATA TABLES

Table B-1 Typical Loading for Personal Computer Systems

Component	Measured Load
Dell Precision T5400 Desktop (Max)	2.4A
15.6", 2.6 GHz Dell Inspiron Laptop	0.75A
24" Dell Monitor	0.58A
HP LaserJet Pro P1102w printer	0.22A idle, 3A printing

Table B-2 Load Data for Preliminary Demand Calculations

Facility Type	VA/m ²	VA/ft ²
BEQ	21-64	2-6
Commissary/Exchange	75- 97	7-9
Cafe/Mess Hall	75-108	7-10
Administration Building	64-108	6-10
Craft/Hobby/Golf Pro	43-54	4-5
Shore Intermediate Maintenance Activity (SIMA)	64-108	6-10
BOQ	22-64	2-6
Warehouse/Exchange	43	4
Child Care	64	6
Chapel	54-75	5-7
Applied Instruction Building	64-108	6-10

Use the above information to aid in estimating demand for transformer sizing for preliminary calculations. As the design progresses, update demand calculations to reflect actual load of the building.

Dwelling Unit Demand Data for Electrical Calculations.

Note: These Tables are provided to aid the Designer of Record in estimating the total demand for “ALL ELECTRIC” dwelling units (including diversity). Size all distribution systems for dwellings for “ALL ELECTRIC”. Use the data below for sizing distribution transformers, service lateral voltage drops and flicker calculations. These tables are not to be used for sizing the service laterals or service entrance conductors.

Table B-3 Dwelling Demand kVA per A/C Size

# of Units	HVAC Diversity	2 Tons		2.5 Tons		3 Tons		3.5 Tons		4 Tons	
		FE	Total	FE	Total	FE	Total	FE	Total	FE	Total
1	1.0	3.89	6.42	4.09	7.25	4.29	8.08	4.93	9.35	5.67	10.72
2	0.85	6.61	10.91	6.95	12.33	7.29	13.74	8.38	15.9	9.64	18.22
3	0.82	8.64	14.91	9.08	16.95	9.52	18.96	10.94	21.95	12.59	25.16
4	0.80	10.27	18.37	10.8	20.91	11.33	23.45	13.02	27.16	14.97	31.13
5	0.77	11.86	21.61	12.47	24.64	13.08	27.68	15.04	32.05	17.29	36.74
6	0.75	13.3	24.69	13.99	26.21	14.67	31.73	16.86	36.75	19.39	42.12
7	0.73	14.7	27.63	15.46	31.61	16.22	35.58	18.64	41.22	21.43	47.24
8	0.72	16.2	30.76	17.01	35.22	17.85	39.68	20.51	45.97	23.59	52.68

Table B-4 Typical A/C Size for Dwelling Units

Dwelling Type	A/C (Tons)	Typical (m ²)	Typical (ft ²)
Mobile Home, Small House	2.0	93	1000
Townhouse, House	2.5	116	1250
Townhouse, Condominium	3.0	140	1500
Condo, House	3.5	163-186	1750-2000
House	4.0	186-279	2000-3000

Table B-5 Demand for Electric Strip Heat

kW Rating of Strip	kVA Demand
5	5.0
10	8.0
15	10.5
20	14.0

FE (Full Electric) is the demand value (with diversity pre-calculated) of the load **without** a summer (air conditioning) or winter (heat strip) HVAC mechanical load included.

"Total" is the demand which **includes** a summer air conditioner load (**Total = FE + air conditioning load**). "Total" does not include the demand associated with resistive heat elements (which may drive the need for larger transformers). **HVAC diversity** = the diversity factor to use for winter HVAC unit demand calculations. It is incumbent on the electrical designer to address loads that are larger than those associated with the summer load. Size the transformer for the summer load unless the winter load calculation is more than 140% of the summer calculation.

Example: A new underground distribution system is being designed for a housing development of duplexes. Each dwelling unit is 1500 ft² (140 m²) with a 3-ton heat pump and 5 kW of strip heat. "Total" load for 8 dwellings (maximum 4 duplexes per transformer – See paragraph "Housing Distribution" in UFC 3-550-01) and 3-ton units = 39.68 kVA (Table B-3). A check of the winter load = FE (Table B-3) + # of strip units x heat strip demand (Table B-5) x HVAC diversity (Table B-3). Winter load = 17.85 + 8 x 5 kW x 0.72 or 46.65 kVA. Summer to Winter load ratio = 46.65/39.68 or 1.18. Size the transformer for the summer load (39.68 kVA). Thus, each 50 kVA pad-mounted transformer must feed 4 duplexes.

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APPENDIX C ELECTRICAL ENGINEERING PRELIMINARY CONSIDERATIONS

Appendix C provides the preliminary design considerations information previously contained in UFC 3-501-03N, *Electrical Engineering Preliminary Considerations*, which has been superseded by UFC 3-550-01. UFC 3-501-03N contained MIL HDBK 1004/1, *Electrical Engineering Preliminary Design Considerations*.

C-1 PRELIMINARY DATA

C-1.1 Load Data.

Before specific electric power sources and distribution systems can be considered, realistic preliminary load data must be compiled. The expected electric power demand on intermediate substations, and on the main electric power supply, shall be calculated from the connected load by applying appropriate factors. Determine these factors by load analysis and by combining loads progressively. To combine the loads, start at the ends of the smallest feeders and work back to the electric power source. Because all loads must be on a common kilowatt (kW) or kilovolt-ampere (kVA) basis, it is necessary to convert motor horsepower ratings to input kilowatts or kilovolt- amperes before combining them with other loads already expressed in those terms. Preliminary electric power load estimates can be made by using the approximate value of one kilovolt-ampere of input per horsepower (hp) at full load. Preliminary estimates of lighting loads may be made by assuming watts per ft² (m²) of building area.

C-1.2 Load Analysis.

To determine appropriate load estimating factors, using the tables and factors below as guides analyze the characteristics of each load. Consider items such as environmental conditions of weather, geographical location, and working hours, as the situation dictates. Notice that when the load densities in w/ft² (m²) are used only in preliminary estimates, the demand and load factors will be used in the final designs.

C-1.3 Terminology.

Five terms are essential to the analysis of load characteristics: demand factor, coincidence factor, diversity factor, load factors and maximum demand. These terms are defined in paragraphs C-1.3.1 through C-1.3.5.

C-1.3.1 Demand Factor.

The demand factor is the ratio of maximum demand of a system to the total connected load of the system or

Equation: Demand factor = Maximum demand load / Total load connected

C-1.3.2 Coincidence Factor.

The coincidence factor is the ratio of the maximum demand of a system, or part under consideration, to the sum of the individual maximum demands of the subdivisions or

Equation: $\text{Coincidence factor} = \text{Maximum system demand} / \text{Sum of individual maximum demands}$

C-1.3.3 Diversity Factor.

The diversity factor is the reciprocal of the coincidence factor or

Equation: $\text{Diversity factor} = \text{Sum of individual maximum demands} / \text{Maximum system demand}$

C-1.3.4 Load factor.

The load factor is the ratio of the average load over a designated period, usually 1 year, to the maximum load occurring in that period or

Equation: $\text{Load factor} = \text{Average load} / \text{Maximum load}$

Load factors in Table C-1 are not to be used when sizing the service conductors.

C-1.3.5 Maximum Demand.

The maximum demand is the integrated demand for a specified time interval, i.e., 5 minutes, 15 minutes, 30 minutes, or other appropriate time intervals, rather than the instantaneous or peak demand.

Table C-1 Factors for Individual Facilities by Navy Category Code (See Note 1)

Navy Code	Description	Demand Factor (%)	Load Factor (%)
100	Operational and Training Facilities:		
121	Aircraft fueling/dispensing facility	40-60	16-20
122	Marine fuel dispensing	40-60	16-20
123 10	Filling station	40-60	13-17
125 16	Miscellaneous POL pipeline facilities	100	13-17
126	Liquid fueling and dispensing-other	40-60	3-7
131	Communications – buildings	60-65	70-75
131 40	Telephone exchange building	55-70	20-25
133 75	Air surveillance radar building	55-70	70-75
137 40	Port control office	55-70	20-25
141 11	Air passenger terminal building	65-80	28-32
141 20	Aircraft fire and rescue station	25-35	13-17
141 30	Aircraft line operations building	65-80	24-28
141 40	Aircraft operations building * EXC 141-70*	65-80	28-32
141 60	Photographic building	65-80	16-20
171 10	Academic instruction building	40-60	22-26
171 20	Applied instruction building	35-65	24-28
171 40	Drill Hall	75-85	3-7
200	Maintenance and Production Facilities:		
211 05	Maintenance Hangar O/H space (high bay)	45-50	28-30
211 06	Maintenance Hangar – 01 space (crew equipment)	45-50	28-30
211 07	Maintenance Hangar – 02 space (administrative)	45-50	28-30
211 10	Aircraft overhaul and repair shop (NARF)	32-38	25-30
211 12	Paint/finishing hangar	65-75	25-27
211 20	Engine overhaul shop (NARF)	32-38	20-25
211 30	Aircraft/engine accessories overhaul shop (NAR)	32-38	25-30
211 75	Parachute/survival equipment	60-65	23-28
211 81	Engine test cell (Non-NARF)	42-48	25-30
211 96	Maintenance, aircraft spares storage (Miscellaneous)	58-63	23-28
212 20	Missile equipment maintenance shop	35-40	15-20
213-10	Drydock	5-10	0.5-1
214-10	Combat vehicle maintenance shop	55-65	20-25
214-20	Automobile vehicle maintenance – noncombat	55-65	20-25
215	Maintenance – weapons/spares	70-80	20-25
216 10	Ammunition rework and overhaul shop	35-40	18-22
216 20	Rocket rework and overhaul shop	35-40	18-22

Navy Code	Description	Demand Factor (%)	Load Factor (%)
216 30	Mines and depth charge rework shop	35-40	15-20
216 40	Torpedo shop	45-55	18-22
216 50	Special weapons shop	35-40	18-22
216 60	Quality evaluation laboratory	55-65	22-27
217 10	Electronics/communications maintenance shop	35-40	20-25
218 20	Construction/weight handling equipment shop	35-45	20-25
218 40	Railroad equipment shop	35-45	15-20
218 50	Battery shop	55-65	20-25
219 10	Public works shop	32-38	18-22
221 10	Aircraft engine assembly plant	32-38	20-25
222 10	Missile assembly buildings	35-40	15-20
222 20	Missile handling launch equipment	35-40	15-20
223 10	Fabrication/assembly building	22-27	24-29
225 10	Small arms plant	15-20	22-27
225 20	Light gun (20mm/51n) plant	15-20	22-27
225 30	Heavy gun (6/161n) plant	16-21	21-26
225 50	Launcher/projector plant	15-20	22-27
226 10	Bag charge filling plant	62-67	23-28
226 15	Case filling plant	35-40	23-28
226 20	Case overhaul tank repair facility	35-40	18-22
226 35	Major-caliber projectile loading plant	35-40	18-22
226 40	Medium-caliber projectile loading plant	35-40	18-22
226 55	Cast high explosives filling plant	35-40	18-22
226 65	Propellant and related chemical facility	30-40	32-38
227 10	Radio and radar equipment plant	50-55	23-28
227 10	Sonar equipment plant	50-55	23-28
228 10	Parachute/survival equipment plant	35-40	20-25
229 10	Asphalt plant	75-80	7-12
229 20	Concrete batching plant	75-80	15-20
229 30	Rock crusher plant	75-80	15-20
229 40	Sawmill	45-55	15-20
300	Research, Development, Test & Evaluation Facilities:		
310 13	Chemistry and Toxicology Laboratory	70-80	22-28
310 15	Materials Laboratory	30-35	27-32
310 19	Physics Laboratory	70-80	22-28
316 10	Ammunition, explosives, and toxics laboratory	28-32	20-25
317 20	Electrical and electronics systems laboratory	20-30	3-7

Navy Code	Description	Demand Factor (%)	Load Factor (%)
400	Supply Facilities		
421	Ammunition storage- installation	75-80
423	Ammunition storage-liquid propellant	75-80	20-25
431 10	Cold storage warehouse	70-75	20-25
441 10	General warehouse Navy	75-80	23-28
441 20	Controlled humidity warehouse	60-65	33-38
441 30	Hazardous/ flammable storehouse	75-80	20-25
441 40	Underground storage	65-70	23-28
441 70	Disposal, salvage, scrap building	35-40	25-20
500	Hospital-Medical Facilities:		
510 10	Hospital	38-42	45-50
530 20	Laboratory	32-37	20-25
540 10	Dental Clinic	35-40	18-23
550 10	Medical Clinic	45-50	20-23
600	Administrative Facilities:		
610 10	Administrative Office	50-65	20-35
620 10	Administrative facility, underground	50-65	35-40
700	Housing and Community Facilities:		
711	Family housing-dwellings	60-70	10-15
712	Substandard: Trailers - family housing	70-75	10-15
714 10	Detached garages	40-50	2-4
721 11	Bachelor enlisted quarters	35-40	38-42
721 12	Bachelor enlisted quarters E5/E6	35-40	38-42
721 13	Bachelor enlisted quarters E7/E9	35-40	38-42
721 30	Civilian barracks GS 01/6	35-40	38-42
721 40	Disciplinary barracks	35-40	38-42
722 10	Detached dining facilities, enlisted men	30-35	45-60
723 20	Latrine, detached	75-80	20-25
723 30	Laundry, detached	30-35	20-25
723 40	Garage, detached	40-50	2-4
724 11	UOPH, W-1/0-2	40-50	20-25
724 12	UOPH, 0-3 and above	40-50	20-25
724 22	Civilian quarters, GS-7/PLS	40-50	20-25
724 30	Dining facility (attached) commissioned personnel	35-40	30-40
730 10	Fire station	25-35	13-17
730 15	Confinement facility	60-65	33-38
730 20	Police station	48-53	20-25

Navy Code	Description	Demand Factor (%)	Load Factor (%)
730 25	Gate/sentry house	70-75	28-33
730 30	Bakery	30-35	45-60
730 35	Enlisted personnel locker room	75-80	18-23
730 40	Laundry/dry cleaning plant	30-35	20-25
730 45	Dependent school – nursery school	75-80	10-15
730 50	Dependent school – kindergarten	75-80	10-15
730 55	Dependent school – grade school	75-80	10-15
730 60	Dependent school – high school	65-70	12-17
730 65	Fallout shelter	80-85	30-35
730 67	Bus station	80-85	30-35
730 70	Decontamination facility	75-80	15-2
730 83	Chapel	65-70	5-25
730 85	Post Office	75-80	20-25
740 01	Exchange retail store	65-70	25-32
740-18	Bank	75-80	20-25
740 23	Commissary including backup storage	55-60	25-30
740 26	Installation restaurant	45-75	15-25
740 30	Exchange auto repair station	40-60	15-20
740 36	Hobby shop, art/crafts	30-40	25-30
740 40	Bowling Alley	70-75	10-15
740 43	Gymnasium	70-75	20-45
740 46	Skating rink	70-75	10-15
740 50	Field house	75-80	7-12
740 53	Indoor swimming pool	55-60	25-50
740 56	Theater	45-55	8-13
740 60	Commissioned officers' mess, open	55-60	15-20
740 63	Enlisted personnel club	55-60	18-23
740 66	Petty officers' mess, open	55-60	18-23
740 70	Mess open, E-7 through E-9	55-60	15-20
740 76	Library	75-80	30-35
740 80	Golf club house	75-80	15-20
740 86	Exchange installation warehouse	58-63	23-28
740 88	Educational services office	70-75	30-35
760 10	Museum/memorial building	75-80	30-35
800	Utilities and Ground Improvements:		
811 10	Electric power plant-diesel	60-65	58-63
811 25	Electric power plant-steam	60-65	58-63

Navy Code	Description	Demand Factor (%)	Load Factor (%)
811 45	Electric power plant-gas turbine	60-65	58-63
811 60	Standby generator plant	75-80	5-10
812 20	Street lighting	95-...	46-...
812 40	Perimeter/security lighting	80-85	22-27
813 20	Substation, more than 499 kV	25-30	20-25
821 12	Fossil fuel heating plant – medium	55-60	30-60
821 22	Fossil fuel heating plant – large	55-60	30-60
821 50	Non-nuclear steam plant	50-55	30-40
826 20	Chilled water plant 25/100 tons	60-70	25-30
827 20	Air conditioning-chilled water transmission/distribution system – medium (25/100 tons)	60-70	25-30
831 10	Combination sewage and industrial waste treatment plant	60-70	15-20
832 30	Sewage-industrial waste pumping station	55-60	30-35
833 22	Incinerator building and incinerator	55-60	15-20
841 10	Water treatment facilities	60-80	15-25
841 50	Wells-potable water	60-80	15-25
843 20	Fire protection pumping station	Do not include – operate for test off peak.	
890 20	Compressed air plant	45-50	25-30
890 42	Air-conditioning plant	60-70	25-30
Miscellaneous Operational and Training Facilities:			
125 10	POL pipeline		
132 10	Antenna – communications	95-...	46-...
Miscellaneous Facilities for Ship Repair and Shipbuilding:			
Ship repair shops:			
213 41	Central tool shop – (06) (E)	32-37	23-28
213 42	Shipfitting shop – (11) (A)	22-27	24-29
213 43	Sheet metal shop (17) (B)	10-15	15-20
213 44	Forge and heat treatment space (23) (F)	25-30	13-18
213 49	Inside machine shop – (31) (G)	16-21	21-26
213 53	Boiler making shop – (41) (D)	12-17	14-19
213 54	Electrical shop – (51) (M)	33-38	20-25
213 55	Pipefitting shop – (56) (J)	22-27	17-22
213 56	Woodworking shop – (64) (R)	25-30	21-26
213 59	Abrasive blast facility	30-35	10-15
213 60	Paint and blasting shop – (71) (S)	50-55	23-28
213 61	Riggers shop – (72) (T)	50-55	20-25
213 62	Sail loft	35-40	20-25

Navy Code	Description	Demand Factor (%)	Load Factor (%)
213 63	Foundry – (81) (K)	35-40	22-27
213 64	Patternmaking shop – (94) (X)	28-33	12-17
213 67	Pumphouse, drydocks	75-80	0.1-0.2
Miscellaneous Facilities for Naval Ordnance Manufacture:			
226	Ammunition components building	15-20	20-25
226	Manufacturing	30-45	17-32
226	Explosive loading	65-70	25-30
226	Miscellaneous explosives storage and handling	65-70	5-10
226	Assembly building	40-50	20-25
226	Detonator building	65-70	20-25
226	Pelleting	40-50	20-25
226	Plastic beading	55-60	18-23
226	Sewing room	35-40	25-30
226	Projective assembly breakdown	55-60	18-23
226	Machine shop	16-21	21-26
226	Phosphorous plant	35-40	25-30
226	TNT detonator (military)	35-40	15-20
226	Ammunition tank box assembly	35-40	15-20
226	Box emptying	35-40	15-20
226	Plating maintenance	35-40	18-23
226	Mixing	40-45	18-23
226	Segregation fleet return	35-40	15-20
226	Plaster load	35-40	15-20
	Fluoroscope building	45-50	18-23
	Tank building rocket	40-45	15-20
	Hydrostatic test	35-40	15-20
	Phosphorous loading	35-40	15-20
226	Vacuum and hydraulic pump building	35-40	12-17
226	Cable drive	35-40	12-17
226	Dryer building	75-80	3-8
Miscellaneous Production Facilities:			
229 50	Printing Plant	45-55	25-30
Miscellaneous Storage Facilities:			
750	Community Facilities – morale, welfare, and recreation – exterior	Determine by load count and time.	
750 30	Outdoor swimming pool installation	80-85	20-25
750 54	Band stand	75-80	15-25
Miscellaneous Facilities for Utilities and Ground Improvements:			

Navy Code	Description	Demand Factor (%)	Load Factor (%)
821 09	Heating plant building (condensate)	55-60	25-40
821 09	Heating plant building (heating)	55-60	30-35
833 40	Garbage house	75-80	20-25
841	Potable water – supply/treatment/storage	Determine by load count and time.	
845 20	Pipeline nonpotable water	55-60	3-8
852 30	Pedestrian bridge	80-85	20-25
872 20	Guard and watch towers	80-	46-
890 20	Compressed air plant	60-65	20-25

Note 1: Demand factors include allowance for system loss.

C-2 ESTIMATION OF LOADS.

C-2.1 Preparation of Load Data.

Load data are generally computed in steps such as:

- a. individual loads,
- b. area loads, and
- c. activity loads.

A particular design problem may be limited to step a), to steps a) and b), or may encompass steps a), b), and c). This section outlines each step as a separate entity, dependent only on previous steps for data. Paragraphs C-2.2 through C-2.4.4 describe the three loads.

C-2.2 Individual Loads.

Individual loads are those with one incoming service supplying utilization voltage to the premises. In general, these loads would comprise single structures. Large structures could contain more than one function: for example, aircraft operations, aircraft fire and rescue stations, and photographic buildings. Under this condition, factors that have been developed and keyed to Navy category codes (refer to Table C-1) would be used. In this case, the factors listed under Navy category Code 141 40, 141-20, and 141-60, respectively, would be combined to obtain the total load.

C-2.2.1 Lighting.

To eliminate lighting loads, divide a facility area into its significant components by function (for example, office, storage, mechanical, and corridor). Determine the average lighting level and type of light source for each area. Consider requirements for supplementary lighting (for example, floodlighting, security lighting, and special task

lighting). Preliminary load estimates may be made based on applicable ASHRAE 90.1 lighting power allowances.

C-2.2.1.1 Small Appliance Loads.

Small appliance loads shall include those served by general purpose receptacles. In general, the dividing of areas by function for estimating lighting loads will serve for estimating small appliance loads. The determination of loads requires not only the knowledge of the function of an area, but to what extent its occupants use small appliances. For example, an office area demand may average about 1 W/ft² (10.76 W/m²) but could vary from a low of 0.5 W/ft² (5.38 W/m²) to a high of 1.5 W/ft² (16 W/m²), depending on the specific tasks to be performed. A minimum of 0.1 W/ft² (1 W/m²) for auditoriums to a maximum of 2.5 W/ft² (27 W/m²) for machine shops is possible, although the upper limit would occur very rarely. Mechanical spaces in building storage areas and similar spaces in which outlets are provided but infrequently used are usually neglected in computing loads, except for special cases.

C-2.2.1.2 Electric Power Loads.

Electric power loads shall include all loads other than lighting loads and those served by general purpose receptacles. Electric power loads comprise the environmental system electric power requirements and the facility occupancy equipment electric power requirements.

C-2.2.1.3 System Loss.

A system loss of approximately 6 percent, based on calculated maximum demand, should be added to the building load.

C-2.2.2 Demand and Load Factors.

The demand and load factors for a specific facility will vary with the division of load and hours of usage. Refer to Tables C-2 and C-3 for values that can be applied to determine demand and load factors. Table C-4 is included as a guide and an aid in illustrating the method of determining loads, which are calculated for a particular type of building, such as an academic and general instruction building (Navy Code 171-10). The values given are empirical and will vary from activity to activity and may vary from one facility to another within an activity. Annual hours use of demand must be determined for each case in accordance with methods of operation and characteristics of the installation. Demand factors and load factors for individual facilities by the Navy category code given in Table C-1 are based on a survey of existing Navy facilities and past experience. Such factors should be used for quick estimating purposes and as a check when a more precise calculation is undertaken (refer to Table C-4).

C-2.2.2.1 Guides for Demand Factors.

For guides on selection of demand factors, refer to Table C-5.

C-2.2.2.2 Guides for Load Factors.

Guides for the selection of load factors indicate the need for special considerations (refer to Table C-6). Factors in the middle of the range are for the average facility at the peacetime shore establishment and should be used unless the guides in Table C-6 indicate otherwise.

Table C-2 Demand Factors for Specific Loads (See Note 1)

Types of Loads	Estimated Range of Demand Factor (%)	Quick Estimating Demand Factor (%)
Motors: General purpose, machine tool, cranes, elevators, ventilation, compressors, pumps, etc.	20–100	30
Motors: Miscellaneous, fractional, and small appliances	10–50	25
Resistance ovens, heaters, and furnaces	80–100	80
Induction furnaces	80–100	80
Lighting	65–100	75
Arc welders	25–50	30
Resistance welders	5–40	20
Air-conditioning equipment	60–100	70
Refrigeration compressors	40–100	60

Note 1: Demand factors include allowance for system loss.

Table C-3 Annual Hours of Demand Usage for Specific Loads

Types of Loads	Quick Estimating Hours of Use		
	1-Shift Operation	2-Shift Operation	3-Shift Operation
Motors: General purpose	1,200	1,600	2,000
Motors: Miscellaneous, fractional, and small appliances	1,500	1,800	2,100
Resistance ovens, heaters, and furnaces	1,000	1,300	1,600
Induction furnaces	900	1,200	1,500
Lighting	2,200	2,800	3,500
Arc welders	500	700	900
Resistance welders	500	700	900
Air-conditioning equipment			
Less than 1,500 cooling degree days	1,200	1,400	1,600
1,500 to 2,500 cooling degree days	1,600	1,800	2,000
More than 2,500 cooling degree days	2,200	2,500	2,800

Table C-4 Academic Building (Code 171-10) Demand and Load Factor Calculations (See Note 1)

		Motors		Lighting	Air Conditioning	Total
		General	Miscellaneous Fractional & Small Appliances			
1.	Watts/square foot (Watts/square meter)	1.0 (10)	1.0 (10)	2.7 (26.5)	4.5 (45)	9.2 (91.5)
2.	Connected load	100 kW	100 kW	265 kW	450 kW	915 kW
3.	Specific load demand factor	30%	10%	75%	70%	
4.	Maximum demand load (line 2 x line 3)	30 kW	10 kW	200 kW	315 kW	555 kW
5.	Annual operating (1-shift) usage	1,200 hrs.	1,500 hrs.	2,200 hrs.	1,600 hrs.	
6.	Annual usage in megawatt hours (line 4 x line 5)	36	15	440	504	995
7.	Demand factor Formula = Line 4 / Line 2 (1)	-	-	-	-	60%
8.	Load factor Formula = Line 6 / (Line 4 x 8760 hours) (4)	-	-	-	-	20%

Note 1: Calculated for a 100,000 square-foot (10,000 square meter) building. See Tables C-2 and C-3 for data used for lines 3 and 5 respectively. Load growth is included in connected load. Maximum demand load includes allowance for system loss. For this illustration, the coincidence factor occurring when individual demand loads are added is considered to be 1.00 and has not been shown.

Table C-5 Guides for Selection of Demand Factors

Select factors in upper half of range for conditions described below	Select factors in lower half of range for conditions described below
GENERAL GUIDES	
Facilities in active use and approaching maximum capacity.	Facilities of intermittent use or not being fully utilized.
Loads predominantly lighting.	Motor loads made up of a number of independently operated small motors.
Loads predominantly heating.	Motor loads controlled automatically unless control depends upon weather conditions.
Loads dominated by one or two large motors.	
OPERATIONAL AND TRAINING FACILITIES	
Instruction buildings with little or no electric equipment.	Large instruction buildings with electrical demonstration and training equipment.
Communications buildings with telephonic equipment only.	
MAINTENANCE AND PRODUCTION FACILITIES	
Shops and facilities when engaged in mass production of similar parts.	No special guides.
RESEARCH, DEVELOPMENT, AND TEST FACILITIES	
Facilities used for repetitive testing of material or equipment.	No special guides.
SUPPLY FACILITIES	
Refrigerated warehouses in South.	Warehouses with many items of electric materials
Dehumidified warehouses in Mississippi Valley and along seacoasts.	handling equipment, including cranes and elevators.
Warehouses for active storage.	
HOSPITAL AND MEDICAL FACILITIES	
No special guides.	No special guides.
ADMINISTRATIVE FACILITIES	
Large administrative buildings with mechanical ventilation and air conditioning.	Casual offices, offices used infrequently by foremen and supervisors, or offices in which there is little prolonged desk work.
Note: Group large administrative buildings separately only when administration is a significant part of total activity load.	
HOUSING AND COMMUNITY FACILITIES	
Enlisted barracks at training centers.	Food service facilities where load is primarily cooking and baking.
Public quarters where less than 25 family units are involved.	
Restaurants, exchanges, cafeterias, and other food service facilities when gas or steam is primary fuel.	
UTILITIES AND GROUND IMPROVEMENTS	
Central heating plants serving extended areas and buildings.	No special guides.
Water pumping stations serving extended areas or carrying most of load of water systems.	
Central station compressed air plants.	

Table C-6 Guides for Selection of Loads Factors

Select factors in upper half of range for conditions described below	Selection factors in lower half of range for conditions described below
GENERAL GUIDES	
Facilities operated on two or more shifts. Loads that are primarily fluorescent or high intensity discharge lighting. Many small independently operated motors. Electronic equipment continuously operated for immediate use. Cooling and dehumidification loads for year-round climate control in southern climates. Retail-type service loads and loads that are in active use.	Facilities used intermittently. Inactive facilities. Large motor loads when the load consists of relatively small numbers of motors. Wholesale-type service facilities.
OPERATIONAL AND TRAINING FACILITIES	
Large, permanent instruction buildings in active use.	Special-purpose instruction and training facilities not regularly used.
MAINTENANCE AND PRODUCTION FACILITIES	
Shops with battery charging equipment operated after hours. Active shops at full employment. Mass production shops.	Welding loads or loads made up primarily of welding equipment. Job-order workshops. Shops with large, heavy special function machines. Large induction or dielectric heating loads.
RESEARCH, DEVELOPMENT, AND TEST FACILITIES	
No special guides.	No special guides.
SUPPLY FACILITIES	
Refrigerated and dehumidified warehouses in South or in humid climates. Warehouses for active storage and in continuous use.	Refrigerated warehouses in North. Warehouses with large materials handling equipment loads.
HOSPITAL AND MEDICAL FACILITIES	
Clinics and wards with daily operating hours and in active use.	No special guides.
ADMINISTRATIVE FACILITIES	
Large, active, well-lighted offices with ventilation and air-conditioning equipment.	No special guides.
HOUSING AND COMMUNITY FACILITIES	
Navy exchanges with food service facilities. Gymnasiums used in connection or with physical therapy. Barracks at schools and training centers.	Restaurants and exchanges serving only one meal a day. Restaurants and exchanges with gas steam food preparation equipment. Chapels used primarily on Sundays. Subsistence buildings serving less than four meals a day. Laundries with dry cleaning plants. Exchanges operated less than 8 hrs/day Gatehouses operated less than 24 hrs/day
UTILITIES AND GROUND IMPROVEMENTS	
Heating plants that supply both heating and process steam. Water plants with little power load. Air-conditioning plants for year-round control of environment in South. Compressed air plants consisting of many banked compressors operating automatically.	Heating plants in South.

C-2.2.3 Load Growth.

Determine the requirements for load growth for anticipated usage and life expectancy with particular attention to the possibility of adding heavy loads in the form of air conditioning, electric heating, electric data processing and electronic communication equipment. Before determining the size of service and method of distribution to a facility, an economic analysis shall be made to determine the most feasible way of serving this future load. This analysis shall include the effect on the existing installation if future loads require reinforcing or rehabilitation of the service system.

C-2.2.4 Emergency Loads.

The determination of emergency electric power requirements is based on three types of loads (refer to Section 3 for types of loads to be included in each category):

- Minimum essential load,
- Emergency load for vital operations, and
- Uninterruptible (no-break) load.

When the three categories of emergency electric power requirements have been ascertained, determine where local emergency facilities are required, where loads may be grouped for centralized emergency facilities, and what loads are satisfied by the reliability of the general system. Base the above determinations on safety, reliability, and economy, in that order.

C-2.3 Area Loads.

Area loads consist of groups of individual facility loads served by a subdivision of the electric distribution system. The term “area” applies to the next larger subdivision of an overall distribution system. Demand loads for an area must be known for sizing the distribution wiring and switching, and in a large installation will be required for the design of substations serving the area. Table C-7 gives an example of how the coincident peak demand is calculated.

C-2.3.1 General Loads.

To obtain the general load, add roadway lighting, area lighting, obstruction lighting, and other loads not included in individual facility loads.

C-2.3.2 Coincidence Factor.

Determine the maximum expected demands, taking into consideration whether loads within the area peak at the same or at different times.

C-2.3.2.1 Relationships.

Figure C-1 indicates the relationship that exists between the load factor of individual facility loads and the coincidence of their peak demands with the peak demand of the group. This relationship was developed by a study of the loads of selected naval shore activities and by the application of factors developed to the formulas published by IEEE. For collateral reading on this subject, refer to IEEE Technical Paper 45-116 Coincidence-Factor Relationship of Electric Service Load Characteristics. Table C-8 is Figure C-1 in tabular form with values shown to the nearest whole dollar, except for low load factors.

C-2.3.2.2 Selection.

Areas with relatively insignificant residential type loads, where the load curve indicates that most of the electric power consumed in the area is used during the 40 normal working hours of a week, have coincidence factors at the higher end of the range.

C-2.3.2.3 Electric Power Consumption.

In general, areas where large amounts of electric power are consumed outside the usual 40 working hours a week have a coincidence factor at the lower end of the range (examples are hospitals, areas operated on two or more shifts, or large barracks type activities). The upper limit of the range is for the 40 hour per week operation; the lower limit is for a 60 hour per week operation.

C-2.3.2.4 Influencing Factors.

The number of individual loads in a group and their load factors influence the individual load coincidence factor. The coincidence factors in Table C-8 apply for groups of 100 or more individual loads. These coincidence factors can also be used for groups of as few as 30 to 50 individual loads if their load factor is 0.30 or greater. For areas of fewer individual loads, the mathematical relationship from IEEE Technical Paper 45-116 provides a basis for estimating the connected coincidence factor as shown by the following equation:

Equation: $E_n = E_t + (1 - E_t)/n$

Where:

E_n = The individual load coincidence factor applied with a given number of consumers.

E_t = The coincidence factor as given in Table C-8 in hundredths.

n = The number of individual loads in a group.

C-2.3.2.5 Individual loads.

The coincidence factors in Table C-8 are based on the individual loads in a group being substantially the same size. If a single load or small group of loads in an area represent a substantial percentage of overall load, the coincidence factors as given in Table C-8 will no longer apply. With an individual load, increase the coincidence factor to a value commensurate with its effect on the overall area load. This is not in addition to, but in place of, the normal coincidence factor. Determine this value by considering intergroup coincidence factors given in paragraph C-2.3.2.

An example of facility Navy Code 211-70 is presented in Table C-7.

For a small group, determine the coincidence peak load, and to this apply the appropriate intergroup coincidence factor to obtain the coincidence peak load for the area.

C-2.3.2.6 Groups of Loads or Areas.

Where groups of loads within an area, or areas within a facility are combined, an additional intergroup coincidence factor will exist. For loads of similar nature, the intergroup coincidence factor should be in the range 0.93 to 1.00. If loads of a varying nature (evening loads and daytime loads) are combined, the intergroup coincidence factor should be in the range of 0.70 to 1.00. The lower values will occur when magnitudes of the loads are nearly balanced, and the higher ones when the combined load is predominantly one type.

Table C-7 Method of Calculating Coincident Peak Demand

Navy Code	Description	Total Connected Load (kW)	Demand Factor (%)	Maximum Demand (%)	Load Factor (%)	Coincidence Factor (%)	Coincidence Peak (kW)
125 16	Fuel oil pump house						
125 16	Fuel oil pump house						
125 16	Total	0.3	100	0.3	52	52(1)	0.2
125 20	Filling station	3.0	60	1.8	18	57(1)	1.0
125 20	Filling station building	0.3	80	0.2	20	61(1)	0.1
131 35	Receiver building	2.1	65	1.4	72	79	1.1
131 50	Transmitter building						
131 50	Transmitter building						
131 50	Total	37.2	65	24.2	72	79	19.1
133 25	Tacan building	0.7	65	0.5	72	79	0.4
133 75	Radar building	1.2	70	0.8	72	79	0.6
141 20	Aircraft fire and rescue station	8.0	30	2.4	15	52(1)	1.2
141 40	Aircraft operations building	80.2	80	64.2	28	68(1)	43.6
141 60	Photographic building	10.5	70	7.4	18	57(1)	4.2
171 10	Academic instruct building						
171 10	Academic instruct building						
171 10	Academic instruct building						
171 10	Academic instruct building						
171 10	Total	47	60	28.2	22	62(1)	17.5
171 35	Operational Trainer Facility	0.1	80	0.1	15	52(1)
211 10	Aircraft overhaul and repair shop	7,600	38	2,890	25	95(2)	2,745
211 12	Paint/finishing hangar	127	70	89.0	26	66(1)	58.3
211 22	Engine preparation and storage shop						
211 21	Engine maintenance shop						

Navy Code		Description	Total Connected Load (kW)	Demand Factor (%)	Maximum Demand (%)	Load Factor (%)	Coincidence Factor (%)	Coincidence Peak (kW)
211	21	Engine maintenance shop						
211	21	Total	405	40	162	15	52(1)	84.2
211	83	Engine test cell	360	45	162	28	68(1)	110
212	20	Missile equipment maintenance shop	3.0	40	1.2	22	62(1)	0.7
214	20	Auto vehicle maintenance facilities						
214	20	Auto vehicle maintenance facilities						
214	20	Auto vehicle maintenance facilities						
214	20	Auto vehicle maintenance facilities						
214	20	Total	370	60	222	25	65(1)	145
730	10	Fire station	14.6	30	4.4	15	52(1)	2.3
							Total	3,325
							System loss 194 (6%)	
							Grand total	3,429

- (1) The coincidence factor has been increased to allow for low load factor and number of facilities in the area. Refer to paragraph C-2.3.2.4, Influencing Factors, of this handbook.
- (2) The coincidence factor has been increased because of the relative magnitude of the load. Refer to paragraph C-2.3.2.5, Individual Loads, of this handbook.

Figure C-1 Theoretical Relationship between Load Factor and Coincidence Factor at U.S. Naval Shore Establishments

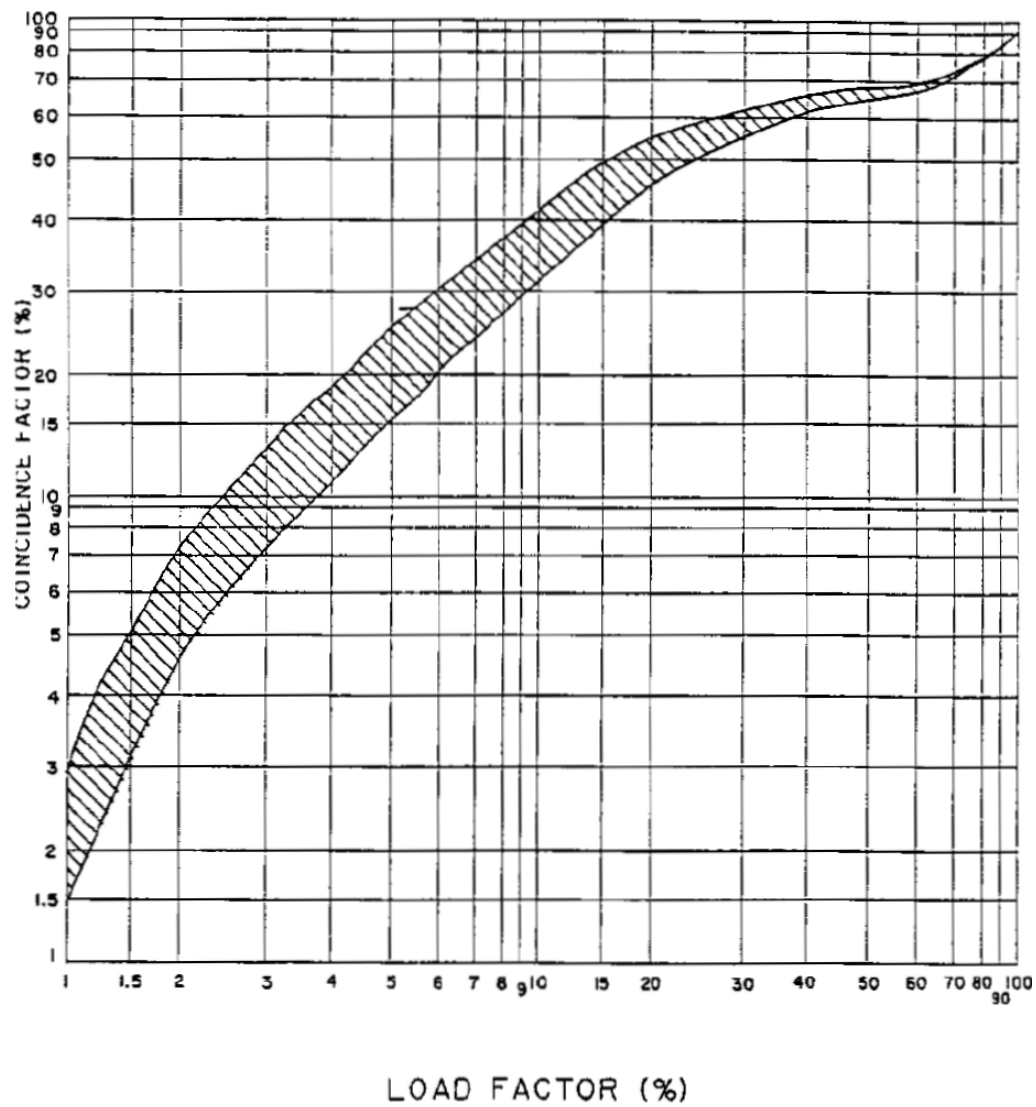


Table C-8 Relationship between Load Factor and Coincidence Factor

Load Factor (%)	Coincidence Factor (%) Loads (hr/wk)		Load Factor %	Coincidence Factor (%) Loads (hr/wk)	
	40	60		40	60
1	2.5	1.5	51	73	69
2	7.5	4.5	52	73	70
3	12	8	53	73	70
4	17	11	54	73	70
5	21	14	55	73	71
6	25	17	56	73	71
7	28	20	57	73	71
8	32	22	58	74	71
9	35	24	59	74	72
10	38	26	60	74	72
11	41	29	61	74	72
12	44	32	62	75	73
13	46	34	63	75	73
14	49	36	64	76	74
15	51	38	65	76	74
16	53	40	66	77	75
17	54	42	67	77	75
18	56	44	68	78	76
19	57	46	69	78	76
20	59	48	70	78	77
21	60	50	71	78	77
22	61	51	72	79	78
23	62	53	73	79	78
24	63	54	74	80	79
25	64	55	75	81	80
26	65	56	76	81	80
27	66	56	77	82	81
28	67	57	78	82	81
29	68	58	79	82	81
30	69	59	80	82	82
31	69	60	81	82	82
32	69	61	82	82	82
33	70	62	83	83	83
34	70	63	84	84	84
35	71	64	85	85	85
36	71	64	86	86	86
37	71	65	87	87	87
38	71	65	88	88	88
39	72	65	89	89	89
40	72	66	90	90	90
41	72	66	91	91	91
42	72	66	92	92	92
43	72	67	93	93	93
44	73	67	94	94	94
45	73	67	95	95	95
46	73	67	96	96	96
47	73	68	97	97	97
48	73	68	98	98	98
49	73	69	99	99	99
50	73	69	100	100	100

C-2.3.3 Load Growth.

In addition to planned expansion, increased application of electric equipment will generate an increase in load. When sizing components, such as transformers or feeders for the area system, consider possible load growth in addition to that included in determination of individual loads.

C-2.3.4 System Losses.

Add distribution system losses to estimated area demands. For a good approximation, use 6 percent of the calculated maximum demand.

C-2.3.5 Emergency Loads.

Review the overall emergency requirements for the area, based on criteria for the facility or as furnished by the using agency, to determine the following:

- a. The emergency loads that may be combined in groups to take advantage of the coincidence factor.
- b. The type of distribution system needed for reliability and to economically satisfy at least the less critical emergency load requirements. This reliability can be provided only if the source of electric power is not the determining factor.
- c. Area loads that must be added to individual emergency loads, for example, security lighting and minimum roadway lighting.

C-2.3.6 Expansion.

The planned development of the area, as shown on the activity general development map, shall be considered for requirements of future expansion.

C-2.4 Activity Loads.

Activity Loads are loads that consist of two or more area loads served from a single electric power source and an integrated distribution system.

C-2.4.1 General Loads.

Follow the approach used in paragraph C-2.3 for area loads. Area loads used for determining activity coincidence demand should be the area coincident demand exclusive of allowance for load growth.

C-2.4.2 Coincidence Factor.

Refer to paragraph C-2.3.2 for the necessary approach. Where dissimilar areas, whether residential, administrative, or industrial, are part of an activity, make a careful analysis of the coincidence factor used.

C-2.4.3 Load Growth.

As for an area, components should be sized after due consideration has been given to load growth. Apply this increase to the coincident demand of the activity.

C-2.4.4 Expansion.

The planned development of the activity, as shown on its general development map, shall be considered for requirements of future expansion.

APPENDIX D GLOSSARY

D-1 ACRONYMS.

AC	Alternating Current
ACSR	Aluminum Conductor Steel-Reinforced
AFI	Air Force Instruction
AL	Aluminum
ANSI	American National Standards Institute
ASHRAE	American Society of Heating, Refrigerating, and Air-Conditioning Engineers
ATS	Acceptance Test Specifications
ATS	Automatic Transfer Switch
BCO	Base Communications Officer
BEQ/BOQ	Bachelor Enlisted Quarters/Bachelor Officer Quarters
BICSI	Building Industry Consulting Services International
BIL	Basic Impulse Level
CAD	Computer Aided Drafting
cal/cm ²	Calories per Centimeter Squared
CATV	Community Antenna Television
CCTV	Closed Circuit Television
CT	Current Transformer
CU	Copper
DC	Direct Current
Degrees C	Degrees Centigrade
Degrees F	Degrees Fahrenheit
DoD	Department of Defense
DOR	Designer of Record

EIA/TIA	Electronics Industries Association/Telecommunications Industry Association
ESS	Electronic Security Systems
ESS	Electric Supply Station
FASS	Facilities Systems Safety program
ft	Feet (or Foot)
ft ²	Foot Squared
GFCI	Ground Fault Circuit Interrupter
GND	Ground
HEMP	High-Altitude Electromagnetic Pulse
HID	High Intensity Discharge
HQUSACE	Headquarters, U.S. Army Corps of Engineers
HVAC	Heating Ventilation and Air Conditioning
hp	Horsepower
ICS	Intelligence Community Standard
IEEE	IEEE (Formerly, Institute of Electrical and Electronic Engineers)
in	Inch
kcmil	Thousand circular mils
kV	Kilovolts
kVA	Kilo-Volt-Ampere
kVAR	Kilo-Volt-Ampere-Reactive
m ²	Meter Squared
mm	Millimeter
MDP	Main Distribution Panel
MVA	Mega-Volt-Ampere
NAVFAC	Naval Facilities Engineering Systems Command

NEC	National Electrical Code
NEMA	National Electrical Manufacturers Association
NESC	National Electrical Safety Code
NETA	International Electrical Test Association
NFPA	National Fire Protection Association
NMCI	Navy and Marine Corps Intranet
O&M	Operation and Maintenance
PCBs	Polychlorinated Biphenyls
PPE	Personal Protective Equipment (Clothing)
PT	Potential Transformer
RCDD	Registered Communications Distribution Designer
RFP	Request for Proposal
RUS	Rural Utility Service
SCIF	Sensitive Compartmented Information Facility
SF6	Sulfur Hexafluoride
SWD	Switch Duty
TSEWG	Tri-Service Electrical Working Group
UFC	Unified Facilities Criteria
UFGS	Unified Facilities Guide Specifications
UL	Underwriters Laboratories
UPS	Uninterruptible Power Supply
V	Volt
VA	Volt-Amp
X/R	Ratio of Reactance to Resistance

D-2 DEFINITION OF TERMS.

Activity: The end user of a base or facility.

Base Communications Officer (BCO): The person(s) responsible for the telecommunications and data infrastructure for a base or facility.

Closed Circuit Television (CCTV): A network of cables and equipment to monitor and transmit video signals throughout a facility.

Community Antenna Television System (CATV): A network of cables, headend and electronic components that process and amplify television and frequency-modulated (FM) radio signals for distribution from one central location to outlets throughout a facility.

Contractor: Person(s) doing actual construction portion of a project.

Corrosive Area: An area identified by the Technical Reviewing Authority as requiring special equipment corrosion mitigation methods.

Designer of Record: The engineer responsible for the actual preparation of the construction documents.

Distribution Device: A facility located within a dwelling unit for interconnection or cross connection of interior telecommunications wiring. Passive cross connect facilities enable the termination of cable elements and their interconnection or cross-connection by means of jumpers and patch cords.

Ductbank: Two or more conduits (or ducts) routed together in a common excavation with or without concrete encasement.

Electric Supply Station: A station that transforms the energy level (voltage) for further bulk distribution at medium voltage levels.

Hot Cap: A sealed insulated cover over the end of a bare energized conductor.

Low Voltage System: An electrical system having a maximum root-mean-square (rms) voltage of less than 1,000 volts.

Medium Voltage System: An electrical system having a maximum RMS AC voltage of 1,000 volts to 34.5 kV. Some documents such as ANSI C84.1 define the medium voltage upper limit as 100 kV, but this definition is inappropriate for facility applications.

Non-Linear Loads: Loads that convert AC to DC and contain some kind of rectifier.

Service: The conductors and equipment for delivering electrical energy from the serving utility or Government-owned system to the wiring system of the premises served.

Service Point: Demarcation for the “service point” (for clarification of the NFPA 70 Article 100 definition): at the building/similar support structure service equipment line side connection.

Site Electrical Utilities: Site Electrical Utilities are the primary electric power distribution to the facilities and other electrical loads, exterior lighting not attached to the building; and telecommunication services (such as fiber optic, copper cable, CATV) required by the Facilities.

Systems Furniture: Modular prewired office furniture.

Technical Reviewing Authority: The “discipline specific” person at the DoD organization who is responsible for signing the project design documents. This is different than the authority responsible for waivers and exemptions required by Mil Std 3007.

Telecommunications Room: An enclosed space for telecommunications equipment, terminations, and cross-connect wiring for horizontal cabling.

TEMPEST: The unclassified name for the studies and investigation of compromising emanations (communications security).

Utilization Electric Supply Station: Equipment such as pole or pad-mounted transformers or secondary unit substations that transforms the energy level (voltage) to a utilization voltage for consumer use.

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APPENDIX E REFERENCES

DEPARTMENT OF DEFENSE

MIL-HDBK-423, *High-Altitude Electromagnetic Pulse (HEMP) Protection for Fixed and Transportable Ground-Based Facilities, Volume I: Fixed Facilities*

MIL-STD-3007 *Standard Practice Unified Facilities Criteria, Facilities Criteria And Unified Facilities Guide Specifications*

MIL-STD-188-125-1A, *High-Altitude Electromagnetic Pulse (HEMP) Protection for Ground-Based C41 Facilities Performing Critical, Time-Urgent Missions, Part 1 Fixed Facilities*

NSTISSI 7000, *TEMPEST Countermeasures for Facilities*

UNIFIED FACILITIES CRITERIA

<https://www.wbdg.org/dod/ufc>

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

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

FC 1-300-09N, *Navy and Marine Corps Design Procedures*

UFC 3-440-01, *Facility-Scale Renewable Energy Systems*

UFC 3-510-01, *Foreign Voltages and Frequencies Guide*

UFC 3-520-01, *Interior Electrical Systems*

UFC 3-520-02, *Facility Energy System Resilience and Reliability*

UFC 3-520-05, *Stationary and Mission Batteries*

UFC 3-530-01, *Interior and Exterior Lighting Systems*

UFC 3-535-01, *Visual Air Navigation Facilities*

UFC 3-540-01, *Engine-Driven Generator Systems for Prime and Standby Power Applications*

UFC 3-540-08, *Utility-Scale Renewable Energy Systems*

UFC 3-550-01, *Exterior Electrical Power Distribution*

UFC 3-550-04: *Installation Microgrid Design*

UFC 3-555-01, *Aircraft Point-of-Use Power Systems*

UFC 3-560-01, *Operation and Maintenance: Electrical Safety*

UFC 3-570-01, *Cathodic Protection*

UFC 3-575-01, *Lightning and Static Electricity Protection Systems*

UFC 3-580-01, *Telecommunications Interior Infrastructure Planning and Design*

UFC 3-600-01, *Fire Protection Engineering for Facilities*

UFC 4-010-01, *DoD Minimum Antiterrorism Standards for Buildings*

UFC 4-010-05, *SCIF/SAPF Planning, Design, and Construction*

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

UFC 4-020-01, *DoD Security Engineering Facilities Planning Manual*

UFC 4-021-01, *Design and O&M: Mass Notification Systems*

UFC 4-021-02, *Electronic Security Systems*

UFC 4-150-02, *Dockside Utilities for Ship Service*

UNIFIED FACILITIES GUIDE SPECIFICATIONS

UFGS 26 05 73, *Power System Studies*

AIR FORCE

AFI 33-210, *Communications and Information Cryptographic Access Program*
<https://apps.dtic.mil/sti/pdfs/ADA404994.pdf>

U.S. ARMY CORPS OF ENGINEERS

DA PAM 385-16, *System Safety Management Guide*

EM 385-1-1, *Safety and Health Requirements*

U.S. NAVY

OPNAV M-5100.23, *Navy Safety and Occupational Health Manual*
<https://www.secnave.navy.mil/doni/SECNAV%20Manuals1/5100.23.pdf>

AMERICAN NATIONAL STANDARDS INSTITUTE (ANSI)

<https://www.ansi.org/>

Note: Many ANSI documents are sponsored or co-sponsored by other organizations, such as NEMA or IEEE.

ANSI C84.1, *Electric Power Systems and Equipment—Voltage Ratings (60 Hz)*

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

<https://www.ashrae.org/>

ASHRAE Standard 90.1, *Energy Standard for Buildings Except Low-Rise Residential Buildings*

Note: Refer to UFC 1-200-02, for applicable publication date

INSTITUTE OF ELECTRICAL AND ELECTRONICS ENGINEERS (IEEE)

<https://www.ieee.org/>

IEEE C2, *National Electrical Safety Code*

IEEE C37.06, *IEEE Standard for AC High-Voltage Circuit Breakers Rated on a Symmetrical Current Basis – Preferred Ratings and Related Required Capabilities*

IEEE C37.13.1, *IEEE Standard for Definite Purpose Switching Devices for Use in Metal-Enclosed Low-Voltage*

IEEE C37.96, *IEEE Guide for AC Motor Protection*

IEEE C57.12.00, *IEEE Standard General Requirements for Liquid-Immersed Distribution, Power, and Regulating Transformers*

IEEE Std 551, *IEEE Recommended Practice for Calculating AC Short-Circuit Currents in Industrial and Commercial Power Systems*

IEEE Std 1547, *IEEE Standard for Interconnecting Distributed Resources with Electric Power Systems*

IEEE Std 1547.4, *IEEE Guide for Design, Operation, and Integration of Distributed Resource Island Systems with Electric Power Systems*

IEEE Std 551, *IEEE Recommended Practice for Calculating Short-Circuit Currents in Industrial and Commercial Power Systems*

IEEE Std 1584, *IEEE Guide for Performing Arc-Flash Hazard Calculations, including Amendments 1 and 2*

IEEE Std 1584.1, *IEEE Guide for the Specification of Scope and Deliverable Requirements for an Arc-Flash Hazard Calculation Study in Accordance with IEEE Std 1584™*

IEEE Std 3002.3TM, *IEEE Recommended Practice for Conducting Short-Circuit Studies and Analysis of Industrial and Commercial Power Systems*

INTERNATIONAL ELECTRICAL TESTING ASSOCIATION (NETA)

NETA ATS, *Acceptance Test Specifications*

NATIONAL FIRE PROTECTION ASSOCIATION

<https://www.nfpa.org/>

NFPA 70, *National Electrical Code*

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

NFPA 780, *Standard for the Installation of Lightning Protection Systems*

PROFESSIONAL ELECTRICAL APPARATUS RECONDITIONING LEAGUE (PEARL)

ANSI/PEARL EERS, *Electrical Equipment Reconditioning Standard for Electrical Apparatus and Equipment used in Commercial and Industrial Applications*

UNDERWRITER'S LABORATORY

UL 489, *Molded-Case Circuit Breakers and Circuit-Breaker Enclosures*